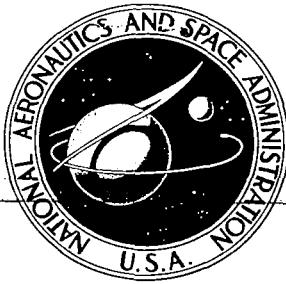


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A COMPREHENSIVE PROGRAM FOR  
THE COMPILATION AND ANALYSIS OF  
THERMAL RADIATIVE PROPERTIES DATA

*by D. P. DeWitt, M. C. Muinzer, and R. S. Hernicz*

*Prepared by*

PURDUE UNIVERSITY

West Lafayette, Ind.

*for*

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • SEPTEMBER 1969

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AND ANALYSIS OF THERMAL RADIATIVE PROPERTIES DATA

By D. P. DeWitt, M. C. Muinzer, and R. S. Hernicz

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Prepared under Contract No. NSR-15-005-037 by  
THERMOPHYSICAL PROPERTIES RESEARCH CENTER  
PURDUE UNIVERSITY  
West Lafayette, Ind.

for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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## FOREWORD

This report was prepared by the Thermophysical Properties Research Center (TPRC), Purdue University, West Lafayette, Indiana, under NASA Contract No. NSR-15-005-037, "Compilation and Analysis of Thermal Radiative Properties Data". The work was administered under the direction of the Office of Advanced Research and Technology, NASA, Washington, D. C., with Mr. Conrad Mook acting as project monitor.

The authors wish to thank Mr. D. W. Gates, Space Sciences Laboratory, NASA-MSFC, and Mr. W. F. Carroll, Materials Section, Jet Propulsion Laboratory, for giving much of their time and advice in many technical phases of the program.

Dr. D. P. DeWitt has been the major investigator and program director. Mr. M. C. Muinzer has served as coordinator for the group consisting of Dr. R. L. Jones, Mr. R. Hernicz, Dr. J. J. Hsia, Mr. D. Garcev, and Mr. R. Dilling. During his brief affiliation with TPRC, Dr. Jones initiated the data evaluation activities for the Series, Volume 7.

The authors wish to acknowledge the direct contributions of TPRC's Scientific Documentation Division, Dr. C. Y. Ho (Head, Data Tables Division); and the staff of the graphics and typing units.



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## **ABSTRACT**

A frequent obstacle in technical developments is the paucity of knowledge on the properties of materials. While there exists an ever increasing volume of literature on the thermal radiative properties, engineering designers are using only a small fraction of what is already available either because it is in a form not directly useful to them or because its existence is not generally known to them, and such information remains buried in the world's literature.

The program described in this report has the objective to identify, collect, extract and analyze data on the thermal radiative properties for general dissemination. Effort is being concentrated on the technological materials of special interest to aerospace requirements under environmental conditions likely to occur in space application. The results of the program will be disseminated through the TPRC SERIES ON THERMOPHYSICAL PROPERTIES OF MATTER presented in three parts: metallic elements and their alloys, nonmetallic solids, and coatings. Data are presented in tabular and graphical forms with accompanying tables giving specifications for the test specimens. For each material four prime properties are identified - emittance, reflectance, absorptance and transmittance - and further grouped according to geometric conditions (hemispherical, normal and angular) and wavelength conditions (spectral, total, solar, and integrated). When sufficient evidence exists, the data has been analyzed and figures of "recommended" values for specific surface and/or environmental conditions are presented. The first part of the program is nearing completion (metallic elements and alloys) and the second and third parts are now well under way.

## INTRODUCTION

The phenomenal growth of science and technology in the last twenty years has brought about a universal appreciation of the fact that present limitations in many technical developments are often a direct result of the paucity of knowledge on the properties of materials. Engineering developments in the years ahead will be closely linked to the research being performed today to contribute to a better understanding of the thermal behavior of materials.

The amount of activity in property determinations, especially thermal radiative properties in the more recent years, attests to the seriousness of the situation with the result that the volume of research literature has increased many fold. Despite the widespread efforts, it can safely be said that the present level of research still falls short of existing needs and anticipated demands. The really disturbing feature is that engineering groups across the nation are using only a small fraction of the information already available, either because it is in a form not directly useful to them or because its existence is not generally known to them and such information remains buried in the world's literature.

There are those who would argue that having full access to the world's literature in a convenient form would not be the total or final solution. Because of the elusive nature of radiative properties - the large influence of surface conditions arising from methods of preparation, thermal history, and environmental conditions - there is little assurance that the data, once located, can be considered reliable or applicable to the problem at hand. This point of view has given rise to a rash of measurement programs necessary for generating data required for specific applications. For the most part, the basic problem - that of gaining insight on how to characterize materials, thereby prescribing the suitability for data to the various applications - has been largely ignored.

Since 1960, the TPRC Retrieval Guide [1]\* has provided a key to the world's literature permitting rapid identification of research papers on radiative properties data. While this is the first and most necessary step, it is not the most convenient form for design engineers. Since 1962, using the Retrieval Guide as the starting point, pertinent literature on radiative properties has been

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\*The numbers in brackets refer to bibliographic citations listed in the section References.

examined and data extracted for the purpose of generating a compendia published as a part of the TPRC Data Book [2]. The program now in progress, and being described in this report, is an extension and enlargement of the modest effort started many years ago.

The current comprehensive program has the objective to concentrate on the technological materials of special interest to aerospace requirements under environmental conditions likely to occur in space applications. The result will be an extensive handbook for design use, containing original research data literature and also "recommended" values for surface and/or environmental conditions that can be well characterized.

This program will bring the world's literature under full and current organizational control. Such a tool, besides giving support to the designers, provides the starting point for further research as the topography of the world's knowledge will make evident the paucities and conflicts in data, as well as provide input for characterization studies using a great bulk of available data. The experience at TPRC using this approach for other properties has been rewarding and significant contributions, particularly in the area of thermal conduction in solids [3], have been made.

#### SCOPE OF THE PROGRAM

The primary objective of this program is to identify, collect, extract, and analyze data on thermal radiative properties for dissemination to and use by engineering design groups. This task, formidable in both its scope and magnitude, presents difficulties in devising an organizational form suitable and convenient for reference by the many interested users of such data.

The materials of interest include all metals, ceramics (excluding glasses), cermets, and coatings of all types especially those particularly suited for thermal control. The temperature range covers from near absolute zero to the material's melting point as only the solid state is being considered. The wavelength range covers from 500 Å to 1000  $\mu$  which encompasses the thermal portion of the spectrum, and special attention is given to solar spectrum conditions.

The thermal radiative properties being presented include the prime properties: emittance, reflectance, absorptance, and transmittance. Additionally, the various sub-properties of these prime ones, denoting geometric and wavelength conditions, are further categorized for efficient retrieval. In as much as the nomenclature for these properties is not universally accepted, it has been necessary to develop a consistent set of terms to unambiguously represent the various sub-properties. For the most part, the nomenclature, fully described in a later section, approximates common usage and lends itself well to the compact and systematic organization required of such a comprehensive work.

The following section of this report deals with the more significant problems in organization of the TPRC SERIES which will be the medium for communication of the information generated by the program.

#### ORGANIZATION OF THE SERIES

The data on thermal radiative properties will be presented in three volumes of the TPRC SERIES ON THERMOPHYSICAL PROPERTIES OF MATTER:

Volume 7 - Thermal Radiative Properties of Metallic Elements  
and Alloys

Volume 8 - Thermal Radiative Properties of Nonmetallic Solids

Volume 9 - Thermal Radiative Properties of Coatings

Each volume will have, in addition to a data section, a text portion concerning the theory, estimation and measurement of the thermal radiative properties of the materials covered in that volume. The purpose of this text is to provide tools for the use and understanding of the data section, and should be a unique contribution in that it contains, in some detail, the experience of the TPRC staff in the evaluation and estimation of property values. See Appendix A for the Contents of this text.

Following the text, there will be a section on data presentation and other related information. In this section the classification - properties and materials - systems are defined, along with the symbols and abbreviations used in the figures and tables. Since these systems are extensive, the user of the book will find it

desirable, if not necessary, to become familiar with this section for maximum efficiency of data retrieval.

### PROPERTY CLASSIFICATION

The primary radiative properties - emittance, reflectance, absorptance, and transmittance - can all be further specified according to geometric and wavelength conditions. In this SERIES the geometric conditions are denoted by the terms angular, normal, and hemispherical. The wavelength conditions are denoted by the terms spectral, total, integrated and solar.

The definition of the terms and their representation by symbols is presented in Appendix B. This section also discusses the classification scheme for grouping related sub-properties for simplified retrieval by the user. What may at first glance appear to be a cumbersome scheme of unnecessary detail is really quite logical to serve the needs of both the casual and experienced user.

### PRESENTATION OF DATA

#### Elements, Alloys and Compounds

The classification scheme for materials in Volumes 7 and 8 is based upon bulk composition rather than surface chemical composition which varies due to weathering, oxidation, etc. This classification scheme is shown in Table 1 which also illustrates the logic for dividing the materials into two volumes, metallic elements and alloys (Volume 7) and nonmetallic solids (Volume 8).

For each material, sub-property data are separately presented in graphical and tabular form, accompanied by a table presenting details of the test conditions and sample preparation.

The format for the presentation of the thermal radiative properties is designed specifically to supply the reader with the aspects of the properties in a comprehensive yet concise form. Each presentation consists of four sections\*; Original Data Plot, Analyzed Data Graph, Specification Tables, and Data Tables, respectively.

\*In certain cases, where there exists only a small amount of data, the Original Data Plot and/or the Analyzed Data Graph may be omitted.

TABLE 1. CLASSIFICATION OF MATERIALS

|    |   | $X_1, \%$   | $X_1 + X_2, \%$ | $X_2, \%$  | $X_3, \%$  |
|----|---|-------------|-----------------|------------|------------|
| 1. | Metallic Elements and Alloys                  |             |                 |            |            |
|    | Metallic Elements                             | > 99.5      | -----           | < 0.2      | < 0.2      |
|    | Alloys  |             |                 |            |            |
|    | Binary Alloys                                 | -----       | $\geq 99.5$     | $\geq 0.2$ | $\leq 0.2$ |
|    |   | -----       | $\geq 99.5$     | $> 0.2$    | $> 0.2$    |
|    | Multiple Alloys                               |             |                 |            |            |
|    |   | -----       | $< 99.5$        | $\geq 0.2$ | $\leq 0.2$ |
|    |   | -----       | $< 99.5$        | $> 0.2$    | $> 0.2$    |
|    |   | $\leq 99.5$ | -----           | $< 0.2$    | $< 0.2$    |
| 2. | Nonmetallic Solids*                           |             |                 |            |            |
|    | Nonmetallic Elements<br>(or Single Compounds) | $\geq 95.0$ |                 | $\leq 2.0$ |            |
|    |   | $< 95.0$    |                 | $\leq 2.0$ |            |
|    | Mixtures                                      |             |                 |            |            |
|    |   | -----       | $\geq 95.0$     | $> 2.0$    |            |
|    |   | -----       | $< 95.0$        | $> 2.0$    |            |

Nomenclature:

$X_1$  = Major Constituent  
 $X_2$  = Second Highest Constituent  
 $X_3$  = Third Highest Constituent  
% = Weight Percent

\*The compositions of non-metals cannot be determined as accurately as those of metals. Therefore, those percentages indicated only serve as approximate limits.

The Original Data Plot is a graphical representation which presents most of the tabulated data. In overcrowded plots, some of the data which are repetitive in nature are omitted.

The Analyzed Data Graph presents a new and powerful approach to increasing the effectiveness of literature data. It is an evaluative review identifying and "recommending" reliable and/or typical data for various surface and/or environmental conditions. The study considers the interrelationships between the sub-properties to give a consistent set of data. Where the data are well characterized and/or highly reliable, it is represented by a solid curve; where there exists some speculation, the data are represented by dashed lines or a shaded band. Following presentation of selected figures from Volume 7, a brief section discusses this approach of data analysis.

The Specification Table gives the most important information: the curve number correlating the information on the Specification Table with that of the figures and Data Table, the reference number corresponding to the number given in the listed references, the year of the publication from which the data were extracted, independent variable range, parameter(s), geometry ( $\theta$ ,  $\theta'$ ,  $\omega$ ,  $\omega'$ ) and the error (%) reported by the author.

The Composition (weight percent), Specification, and Remarks section of the Specification Table provides the available information about the specimen and test conditions. The presentation is standardized in this order:

1. trade name
2. composition (weight percent)
3. film or foil thickness
4. specimen preparation processes
5. surface condition (roughness, etc.)
6. environment
7. type of original presentation of the data (smooth curve, etc.)
8. reference standard
9. other pertinent information
10. author's designation

Following the Specification Table is the Data Table, a tabular presentation of the property values shown on the Figure and described in the Specification Tables.

### Coatings

Considerable effort has been given during the past year to the organization of information on coatings. The term "coatings" is a general one and elusive to define. In the context of the SERIES, a coating is a system consisting of a layer (or layers) of any substance(s) upon a substrate. Of interest are all types of coatings used for many applications - covering protection, finishing, thermal control, etc.

Consideration was given to grouping by application, methods of preparation, and durability. Discussions were held with numerous national experts concerning potential classification systems based on different aspects of coatings. Considering suggestions in light of the purpose for which the SERIES was intended, four major groups of coatings have been delineated which are defined in Table 2.

It should be stressed that this system is still being studied for areas of improvement and that as more data are studied in detail, further analysis of the system structure will be possible.

In processing papers on coatings, it is necessary to include more information in the Specification Tables than is required for the non-coatings. In addition, the following parameters if available are given:

1. thickness of coating
2. substrate
3. condition of substrate
4. application technique
5. environmental effects
6. catalyst (paints)
7. pigment-vehicle ratio (paints)
8. properties of coating (viscosity, porosity, etc.)
9. other pertinent information given by author

Special emphasis will be given to environmental conditions before and during measurements.

TABLE 2. CLASSIFICATION OF COATINGS

Conversion - Diffusion Coatings

A layer of a compound, or mixture of compounds formed by the chemical reaction of the substrate with another material. Classified alphabetically by substrate. Examples:

- a. Anodized Aluminum
- b. Durak B
- c. Oxidized Inconel 702

Contact Coatings

A layer, or layers, of a substance coated on a substrate without a chemical reaction occurring between the coating material and the substrate. Classified alphabetically by coating material itself. Subdivided into the following three types, with examples:

- 1. Inorganic
  - a. Alclad Aluminum
  - b. Flame-sprayed  $\text{Al}_2\text{O}_3$
  - c. Evaporated Gold Film
- 2. Organic
  - a. Teflon
  - b. Vinyl
- 3. Special Purpose
  - a. Anti-reflection Coatings
  - b. Second Surface Mirrors

Pigmented Coatings (Vitreous enamels and paints)

A mixture of pigment and vehicle applied to a substrate. Classified alphabetically by pigment. Subdivided into the following three types, with examples:

- 1. Inorganic Pigment
  - a. Paint ( $\text{Sb}_2\text{O}_3$  + nitrocellulose)
  - b. Paint ( $\text{TiO}_2$  + epoxy resin)
  - c. Paint ( $\text{ZnO}$  + silicone)
- 2. Organic Pigment
  - a. Paint (Vinyl-phenolic)
- 3. Miscellaneous Paints
  - a. Dynalac H-U
  - b. Korotherm HT
  - c. Colors

Uncharacterized Coatings

Classified alphabetically by commercial name.

## MATERIAL INDEX AND REFERENCE LISTINGS

The Material Index is an alphabetical listing of all materials contained in the SERIES volume together with their respective page numbers for each sub-property. Many commercial designations are cross-indexed with their previous designations and synonyms for complete retrieval of the desired data. The Material Index and Grouping of Materials and List of Figures and Tables from Volume 7 is given in Appendix C.

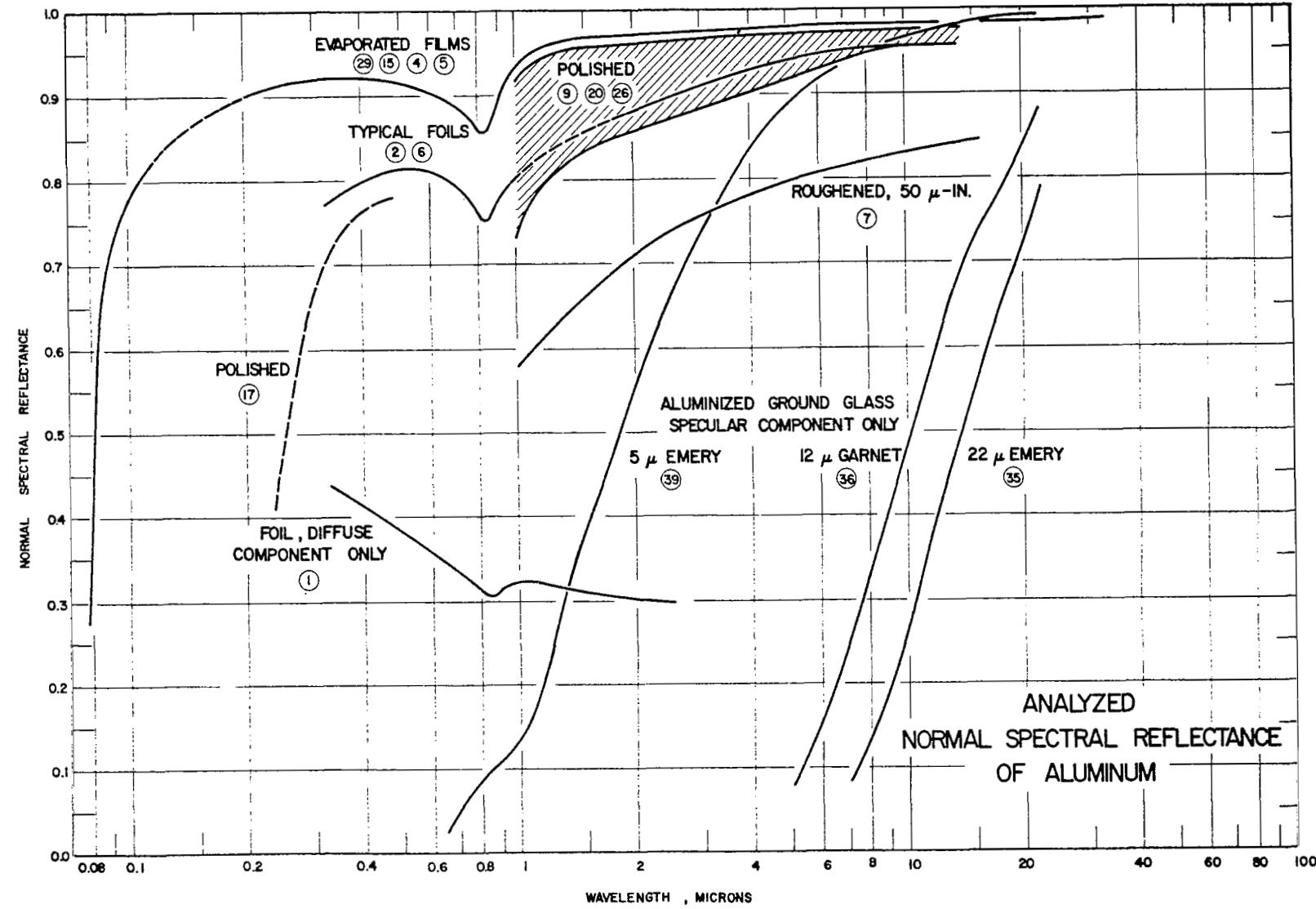
The bibliographic citation for each reference number is furnished in the numerically ordered list of references at the end of the book. Appendix D contains the Reference listing from Volume 7.

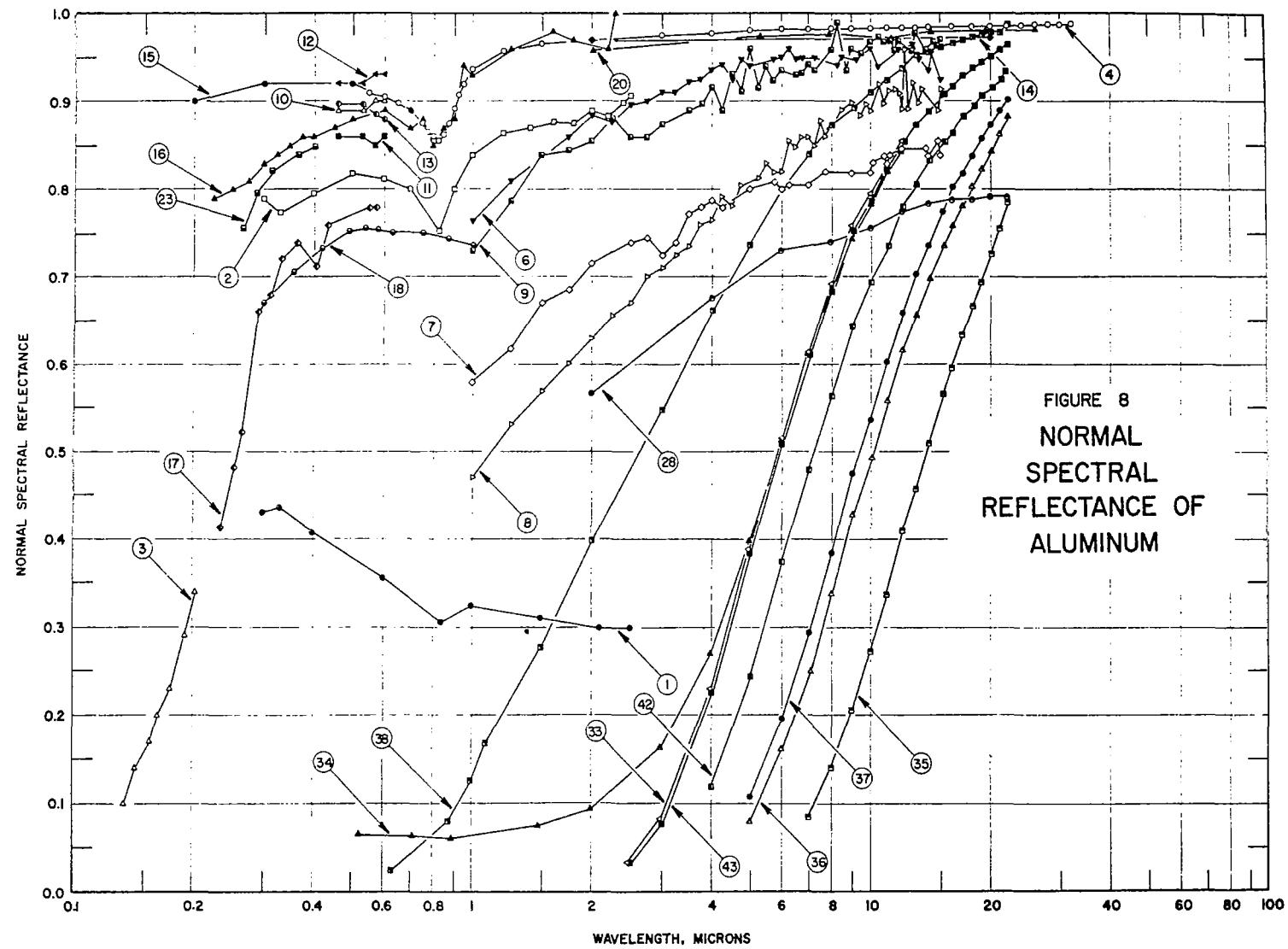
## SAMPLE FIGURES, SPECIFICATION AND DATA TABLES

The following pages contain several selected sets of Figures, Specification and Data Tables for the purpose of demonstrating the presentation of data in the TPRC SERIES, Volume 7. Included are the following:

| Title   | Page |
|---|------|
| Normal Spectral Reflectance of Aluminum                   | 10   |
| Normal Spectral Absorptance of Copper                     | 18   |
| Normal Spectral Transmittance of Gallium                  | 22   |
| Hemispherical Total Emittance of Molybdenum               | 26   |
| Normal Spectral Emittance of Tungsten                     | 32   |
| Normal Total Emittance of Iron + Chromium + Nickel Alloys | 44   |

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## SPECIFICATION TABLE NO. 8 NORMAL SPECTRAL REFLECTANCE OF ALUMINUM

| Curve No. | Ref. No. | Year | Temperature K | Wavelength Range, $\mu$ | Geometry<br>$\theta$ $\theta'$ $\omega'$ | Reported Error, % | Composition (weight percent), Specifications and Remarks   |
|-----------|----------|------|---------------|-------------------------|--|-------------------|--|
| 1         | 123      | 1960 | 298           | 0.30-2.50               | $\sim 0^\circ$ $2\pi$                    |                   | Foil; MgO reference; diffuse reflectance.  |
| 2         | 123      | 1960 | 298           | 0.30-2.50               | $\sim 0^\circ$ $2\pi$                    |                   | Foil; cemented on fiberglass laminate; MgO reference.  |
| 3         | 124      | 1941 | 298           | 0.1347-0.2026           | $\sim 0^\circ$ $\sim 0^\circ$            |                   | An opaque film on glass deposited by the evaporation process; measured in vacuum (0.001 mm Hg).  |
| 4         | 125      | 1962 | 298           | 0.550-32                | $5^\circ$ $5^\circ$                      | $\pm 0.1$         | 99.998 pure; Al film (0.065 to 0.11 $\mu$ thick), evaporated at $1 \times 10^{-5}$ mm Hg, supersmooth fused quartz optical flats as substrate, no watermarks or other blemishes on the substrate surface, no shadows or streaks in the evaporated Al film; freshly prepared; measured in dry nitrogen.               |
| 5         | 125      | 1962 | 298           | 0.550-32                | $5^\circ$ $5^\circ$                      | $\pm 0.1$         | 99.998 pure; Al film (0.065 to 0.11 $\mu$ thick), evaporated at $1 \times 10^{-5}$ mm Hg, supersmooth fused quartz optical flats as substrate, no watermarks or other blemishes on the substrate surfaces, no shadows or streaks in the evaporated Al film; aged in air for several weeks; measured in dry nitrogen. |
| 6         | 126      | 1953 | 300           | 1.00-15.00              | $5^\circ$ $2\pi$                         | $\pm 2.6$         | Foil (0.001 in. thick); data extracted from smooth curve; converted from $\beta$ ( $2\pi, 5^\circ$ ).  |
| 7         | 126      | 1953 | 300           | 1.00-15.00              | $5^\circ$ $2\pi$                         | $\pm 2.6$         | Disc (0.032 in. thick); polished, roughened (roughness approximately 50 microinches); data extracted from smooth curve; converted from $\beta$ ( $2\pi, 5^\circ$ ).  |
| 8         | 126      | 1953 | 300           | 1.00-15.00              | $5^\circ$ $2\pi$                         | $\pm 4.3$         | Disc; commercial finish; data extracted from smooth curve; converted from $\beta$ ( $2\pi, 5^\circ$ ).   |
| 9         | 126      | 1953 | 300           | 1.00-15.00              | $5^\circ$ $2\pi$                         | $\pm 2.7$         | Disc; polished; data extracted from smooth curve; converted from $\beta$ ( $2\pi, 5^\circ$ ).  |
| 10        | 127      | 1955 | 298           | 0.46-0.60               | $10^\circ$ $2\pi$                        | $\pm 0.5$         | 99 pure; vacuum deposited on glass; measured immediately after removed from vacuum chamber; calculated by authors from $\rho = 1 - \alpha$ using an incandescent tungsten lamp as source.  |
| 11        | 127      | 1955 | 298           | 0.46-0.60               | $10^\circ$ $2\pi$                        | $\pm 0.5$         | Above specimen and conditions except exposed to the atmosphere for 8 days.   |
| 12        | 127      | 1955 | 298           | 0.46-0.60               | $10^\circ$ $2\pi$                        |                   | 99.99 pure; vacuum deposited on glass; measured immediately after removed from vacuum chamber; calculated by authors from $\rho = 1 - \alpha$ using an incandescent tungsten lamp as source.   |
| 13        | 127      | 1955 | 298           | 0.46-0.60               | $10^\circ$ $2\pi$                        |                   | Above specimen and conditions except exposed to atmosphere for 8 days.   |
| 14        | 128      | 1962 | 298           | 2.00-20.00              | $\sim 0^\circ$ $2\pi$                    |                   | Evaporated Al on mylar substrate (0.20 $\mu$ thick); illumination solid angle is cone of 0.034 steradians; converted from $\beta$ ( $2\pi, 0$ ).   |
| 15        | 129      | 1964 | 298           | 0.20-0.70               | $\sim 0^\circ$ $2\pi$                    |                   | Evaporated aluminum; data extracted from smooth curve.   |
| 16        | 130      | 1934 | 298           | 0.225-2.3               | $\sim 0^\circ$ $\sim 0^\circ$            |                   | Deposited on a mirror by evaporation.  |
| 17        | 133      | 1934 | 298           | 0.235-0.578             | $\sim 0^\circ$ $\sim 0^\circ$            | 2                 | Disc; cold worked, annealed, etch tested, polished, stored in a solution of NaOH + NaF, washed and dried.  |
| 18        | 220      | 1965 | 298           | 0.300-1.000             | $\sim 0^\circ$ $2\pi$                    |                   | Sand blasted.  |
| 19        | 222      | 1960 | 298           | 0.450-0.600             | $\sim 7^\circ$ $\sim 7^\circ$            | $< 0.16$          | Measured in air.   |
| 20        | 223      | 1962 | 298           | 2.01-25.96              | $\sim 0^\circ$ $2\pi$                    |                   | Polished; converted from $\beta$ ( $2\pi, 0^\circ$ ).  |

SPECIFICATION TABLE NO. 8 (continued)

| Curve No. | Ref. No. | Year | Temperature K | Wavelength Range, $\mu$ | Geometry<br>$\theta$ $\theta'$ $\omega'$ | Reported Error, % | Composition (weight percent), Specifications and Remarks  |
|-----------|----------|------|---------------|-------------------------|--|-------------------|---|
| 21        | 223      | 1962 | 298           | 1.57-25.94              | $\sim 0^\circ$ $2\pi$                    |                   | Above specimen and conditions except after particle impact.   |
| 22        | 223      | 1962 | 77            | 1.91-26.00              | $\sim 0^\circ$ $2\pi$                    |                   | Above specimen and conditions.  |
| 23        | 224      | 1931 | 298           | 0.2653-0.4038           | $\sim 5^\circ$ $2\pi$                    |                   | Acid-etched.  |
| 24        | 216      | 1949 | $\sim 298$    | 1.01-15.00              | $0^\circ$ $2\pi$                         | 5                 | Foil; data extracted from smooth curve.   |
| 25        | 285      | 1962 | 298           | 1.97-13.05              | $\sim 5^\circ \sim 5^\circ$              |                   |   |
| 26        | 336      | 1964 | 298           | 2.00-23.99              | $\sim 0^\circ \sim 0^\circ$              |                   | Polished.   |
| 27        | 336      | 1964 | 298           | 2.00-23.99              | $\sim 0^\circ \sim 0^\circ$              |                   | Above specimen and conditions except cratered with spherical particles ( $100 \mu$ dia) of Zircalloy at $1.5 \text{ km sec}^{-1}$ ; average crater dia $123 \mu$ ; average crater depth $289 \mu$ ; Knoop hardness 22 (100 g load).                         |
| 28        | 336      | 1964 | 298           | 2.00-22.00              | $\sim 0^\circ \sim 0^\circ$              |                   | Different sample, same as above specimen and conditions except cratered with spherical particles ( $100 \mu$ dia) of tungsten at $7 \text{ km sec}^{-1}$ ; average crater depth $54 \mu$ ; average crater depth $183 \mu$ ; Knoop hardness 22 (100 g load). |
| 29        | 341      | 1967 | 298           | 0.079-0.1175            | $\sim 0^\circ \sim 0^\circ$              |                   | Evaporated film; 99.999 pure; evaporated on microscope slide at $3 \times 10^{-8} \text{ mm Hg}$ ; measured in vacuum ( $3 \times 10^{-8} \text{ mm Hg}$ ) 4 min after evaporation.   |
| 30        | 341      | 1967 | 298           | 0.079-0.1175            | $\sim 0^\circ \sim 0^\circ$              |                   | Different sample, same as above specimen and conditions except measured 8 min after evaporation.  |
| 31        | 341      | 1967 | 298           | 0.079-0.1175            | $\sim 0^\circ \sim 0^\circ$              |                   | Different sample, same as above specimen and conditions except measured 12 min after evaporation.   |
| 32        | 341      | 1967 | 298           | 0.079-0.1175            | $\sim 0^\circ \sim 0^\circ$              |                   | Different sample, same as above specimen and conditions except measured 16 min after evaporation.   |
| 33        | 344      | 1963 | 298           | 2.47-12.08              | $\sim 5^\circ \sim 5^\circ$              |                   | Aluminized ground glass; aluminum mirror reference; $\omega' = 0.03 \text{ Sr}$ .   |
| 34        | 344      | 1963 | 298           | 0.52-12.07              | $\sim 5^\circ \sim 5^\circ$              |                   | Aluminized ground steel; aluminum mirror reference; $\omega' = 0.03 \text{ Sr}$ .   |
| 35        | 344      | 1963 | 298           | 7.07-22.10              | $\sim 5^\circ \sim 5^\circ$              |                   | Aluminized ground glass; glass ground with M302 grinding powder ( $\text{Al}_2\text{O}_3$ emery) with average particle size of $22 \mu$ ; aluminum mirror reference; $\omega' = 0.03 \text{ Sr}$ .  |
| 36        | 344      | 1963 | 298           | 5.08-22.19              | $\sim 5^\circ \sim 5^\circ$              |                   | Aluminized ground glass; glass ground with W6 grinding powder ( $\text{Fe}_3\text{Al}_2(\text{SiO}_4)_3$ garnet) with average particle size of $12 \mu$ ; aluminum mirror reference; $\omega' = 0.03 \text{ Sr}$ .  |
| 37        | 344      | 1963 | 298           | 5.07-22.12              | $\sim 5^\circ \sim 5^\circ$              |                   | Aluminized ground glass; glass ground with M 303.5 grinding powder ( $\text{Al}_2\text{O}_3$ emery) with average particle size of $11 \mu$ ; aluminum mirror reference; $\omega' = 0.03 \text{ Sr}$ .   |
| 38        | 344      | 1963 | 298           | 0.63-22.11              | $\sim 5^\circ \sim 5^\circ$              |                   | Aluminized ground glass; glass ground with W10 grinding powder ( $\text{Fe}_3\text{Al}_2(\text{SiO}_4)_3$ garnet) with average particle size of $5 \mu$ ; aluminum mirror reference; $\omega' = 0.03 \text{ Sr}$ .  |
| 39        | 344      | 1963 | 298           | 0.64-22.14              | $\sim 5^\circ \sim 5^\circ$              |                   | Aluminized ground glass; glass ground with M 305 grinding powder ( $\text{Al}_2\text{O}_3$ emery) with average particle size of $5 \mu$ ; aluminum mirror reference; $\omega' = 0.03 \text{ Sr}$ .  |
| 40        | 344      | 1963 | 298           | 3.93-22.23              | $\sim 5^\circ \sim 5^\circ$              |                   | Aluminized dense flint; flint ground with M303.5 grinding powder ( $\text{Al}_2\text{O}_3$ emery) with average particle size of $11 \mu$ ; aluminum mirror reference; $\omega' = 0.03 \text{ Sr}$ .   |

SPECIFICATION TABLE NO. 8 (continued)

| Curve No. | Ref. No. | Year | Temperature K | Wavelength Range, $\mu$ | Geometry<br>$\theta$ $\theta'$ $\omega'$ | Reported Error, % | Composition (weight percent), Specifications and Remarks  |
|-----------|----------|------|---------------|-------------------------|--|-------------------|---|
| 41        | 344      | 1963 | 298           | 3.88-22.25              | $\sim 3^\circ$ $\sim 5^\circ$            |                   | Aluminized plate glass; glass ground with M303.5 grinding powder ( $\text{Al}_2\text{O}_3$ emery) with average particle size of $11 \mu$ ; aluminum mirror reference; $\omega' = 0.03 \text{ Sr}$ .   |
| 42        | 344      | 1963 | 298           | 4.06-22.23              | $\sim 5^\circ$ $\sim 5^\circ$            |                   | Aluminized Pyrex; Pyrex ground with M303.5 grinding powder ( $\text{Al}_2\text{O}_3$ emery) with average particle size of $11 \mu$ ; aluminum mirror reference; $\omega' = 0.03 \text{ Sr}$ .         |
| 43        | 344      | 1963 | 298           | 2.49-22.21              | $\sim 5^\circ$ $\sim 5^\circ$            |                   | Aluminized fused quartz; quartz ground with M303.5 grinding powder ( $\text{Al}_2\text{O}_3$ emery) with average particle size of $11 \mu$ ; aluminum mirror reference; $\omega' = 0.03 \text{ Sr}$ . |

## DATA TABLE NO. 8 NORMAL SPECTRAL REFLECTANCE OF ALUMINUM

[Wavelength  $\lambda$ ,  $\mu$ ; Reflectance  $\rho$ ; Temperature T, K]

| $\lambda$                        | $\rho$ | $\lambda$                        | $\rho$ | $\lambda$                                 | $\rho$ | $\lambda$                                | $\rho$ | $\lambda$                        | $\rho$ | $\lambda$                                | $\rho$ | $\lambda$                                | $\rho$ |
|----------------------------------|--------|----------------------------------|--------|---|--------|--|--------|----------------------------------|--------|--|--------|--|--------|
| <u>CURVE 1</u><br><u>T = 298</u> |        | <u>CURVE 4</u><br><u>T = 298</u> |        | <u>CURVE 5 (cont.)*</u><br><u>T = 298</u> |        | <u>CURVE 6 (cont.)</u><br><u>T = 300</u> |        | <u>CURVE 7</u><br><u>T = 300</u> |        | <u>CURVE 7 (cont.)</u><br><u>T = 300</u> |        | <u>CURVE 8 (cont.)</u><br><u>T = 300</u> |        |
| 0.30                             | 0.430  | 0.550                            | 0.9094 | 0.650                                     | 0.8976 | 2.00                                     | 0.885  | 1.00                             | 0.579  | 13.75                                    | 0.848  | 10.00                                    | 0.890  |
| 0.33                             | 0.435  | 0.600                            | 0.9048 | 0.700                                     | 0.8886 | 2.25                                     | 0.878  | 1.25                             | 0.618  | 14.00                                    | 0.840  | 10.25                                    | 0.898  |
| 0.40                             | 0.408  | 0.650                            | 0.8989 | 0.750                                     | 0.8761 | 2.50                                     | 0.895  | 1.50                             | 0.670  | 14.25                                    | 0.841  | 10.50                                    | 0.920  |
| 0.60                             | 0.355  | 0.700                            | 0.8900 | 0.775                                     | 0.8678 | 2.75                                     | 0.900  | 1.75                             | 0.685  | 14.50                                    | 0.843  | 10.75                                    | 0.898  |
| 0.84                             | 0.305  | 0.750                            | 0.8761 | 0.800                                     | 0.8596 | 3.00                                     | 0.910  | 2.00                             | 0.715  | 14.75                                    | 0.855  | 11.00                                    | 0.900  |
| 1.00                             | 0.325  | 0.775                            | 0.8678 | 0.825                                     | 0.8556 | 3.25                                     | 0.910  | 2.50                             | 0.740  | 15.00                                    | 0.840  | 11.25                                    | 0.912  |
| 1.50                             | 0.311  | 0.800                            | 0.8604 | 0.850                                     | 0.8596 | 3.50                                     | 0.923  | 2.75                             | 0.745  |  |        | 11.50                                    | 0.913  |
| 2.10                             | 0.300  | 0.825                            | 0.8569 | 0.875                                     | 0.8730 | 3.75                                     | 0.925  | 3.00                             | 0.725  | <u>CURVE 8</u><br><u>T = 300</u>         |        | 11.75                                    | 0.910  |
| 2.50                             | 0.300  | 0.850                            | 0.8622 | 0.900                                     | 0.8894 | 4.00                                     | 0.935  | 3.25                             | 0.740  | <u>T = 300</u>                           |        | 12.00                                    | 0.892  |
|                                  | 0.875  | 0.8759                           |        | 0.925                                     | 0.9030 | 4.25                                     | 0.941  | 3.50                             | 0.772  |  |        | 12.25                                    | 0.960  |
| <u>CURVE 2</u><br><u>T = 298</u> |        | 0.900                            | 0.8920 | 0.950                                     | 0.9154 | 4.50                                     | 0.925  | 3.75                             | 0.780  | 1.00                                     | 0.470  | 12.50                                    | 0.892  |
|                                  | 0.925  | 0.9072                           |        | 1.000                                     | 0.9224 | 4.75                                     | 0.948  | 4.00                             | 0.788  | 1.25                                     | 0.530  | 12.75                                    | 0.922  |
|                                  | 0.950  | 0.9192                           |        | 1.200                                     | 0.9585 | 5.00                                     | 0.940  | 4.25                             | 0.780  | 1.50                                     | 0.569  | 13.00                                    | 0.915  |
| 0.30                             | 0.790  | 1.000                            | 0.9360 | 1.500                                     | 0.9658 | 5.25                                     | 0.939  | 4.50                             | 0.793  | 1.75                                     | 0.601  | 13.25                                    | 0.899  |
| 0.33                             | 0.775  | 1.200                            | 0.9596 | 2.000                                     | 0.9699 | 5.50                                     | 0.940  | 4.75                             | 0.800  | 2.00                                     | 0.630  | 13.50                                    | 0.915  |
| 0.40                             | 0.796  | 1.500                            | 0.9676 | 3.000                                     | 0.9736 | 5.75                                     | 0.948  | 5.00                             | 0.800  | 2.25                                     | 0.655  | 13.75                                    | 0.919  |
| 0.50                             | 0.819  | 2.000                            | 0.9718 | 4.000                                     | 0.9758 | 6.00                                     | 0.950  | 5.25                             | 0.802  | 2.50                                     | 0.670  | 14.00                                    | 0.915  |
| 0.60                             | 0.812  | 3.000                            | 0.9765 | 5   | 0.9772 | 6.25                                     | 0.960  | 5.50                             | 0.805  | 2.75                                     | 0.700  | 14.25                                    | 0.900  |
| 0.70                             | 0.800  | 4.000                            | 0.9795 | 6   | 0.9784 | 6.50                                     | 0.948  | 5.75                             | 0.809  | 3.00                                     | 0.710  | 14.50                                    | 0.895  |
| 0.825                            | 0.752  | 5                                | 0.9812 | 7   | 0.9794 | 6.75                                     | 0.950  | 6.00                             | 0.800  | 3.25                                     | 0.725  | 14.75                                    | 0.891  |
| 0.90                             | 0.800  | 6                                | 0.9823 | 8   | 0.9501 | 7.25                                     | 0.950  | 6.25                             | 0.805  | 3.50                                     | 0.735  | 15.00                                    | 0.915  |
| 1.00                             | 0.840  | 7                                | 0.9831 | 9   | 0.9807 | 7.50                                     | 0.945  | 7.00                             | 0.805  | 3.75                                     | 0.760  |  |        |
| 1.20                             | 0.865  | 8                                | 0.9837 | 10  | 0.9812 | 7.75                                     | 0.949  | 7.75                             | 0.821  | 4.00                                     | 0.765  | <u>CURVE 9</u><br><u>T = 300</u>         |        |
| 1.40                             | 0.870  | 9                                | 0.9841 | 11  | 0.9816 | 8.00                                     | 0.945  | 8.00                             | 0.819  | 4.25                                     | 0.792  |  |        |
| 1.60                             | 0.877  | 10                               | 0.9845 | 12  | 0.9821 | 8.25                                     | 0.942  | 8.25                             | 0.821  | 4.50                                     | 0.782  |  |        |
| 1.80                             | 0.877  | 11                               | 0.9849 | 13  | 0.9826 | 8.50                                     | 0.951  | 8.50                             | 0.820  | 4.75                                     | 0.805  | 1.00                                     | 0.731  |
| 2.00                             | 0.890  | 12                               | 0.9854 | 14  | 0.9830 | 9.25                                     | 0.949  | 8.75                             | 0.819  | 5.00                                     | 0.810  | 1.25                                     | 0.788  |
| 2.20                             | 0.884  | 13                               | 0.9857 | 16  | 0.9838 | 10.00                                    | 0.960  | 9.00                             | 0.819  | 5.25                                     | 0.813  | 1.50                                     | 0.840  |
| 2.40                             | 0.899  | 14                               | 0.9861 | 18  | 0.9845 | 10.50                                    | 0.940  | 9.25                             | 0.821  | 5.50                                     | 0.830  | 1.75                                     | 0.845  |
| 2.50                             | 0.905  | 16                               | 0.9868 | 20  | 0.9852 | 10.75                                    | 0.955  | 9.50                             | 0.818  | 5.75                                     | 0.820  | 2.00                                     | 0.855  |
|                                  |        | 18                               | 0.9873 | 22  | 0.9856 | 11.00                                    | 0.949  | 9.75                             | 0.819  | 6.00                                     | 0.820  | 2.25                                     | 0.881  |
| <u>CURVE 3</u><br><u>T = 295</u> |        | 20                               | 0.9878 | 24  | 0.9861 | 11.25                                    | 0.960  | 10.00                            | 0.820  | 6.25                                     | 0.855  | 2.50                                     | 0.860  |
|                                  |        | 22                               | 0.9883 | 26  | 0.9864 | 11.50                                    | 0.951  | 10.25                            | 0.831  | 6.50                                     | 0.849  | 2.75                                     | 0.860  |
|                                  |        | 24                               | 0.9887 | 28  | 0.9867 | 11.75                                    | 0.960  | 10.50                            | 0.831  | 6.75                                     | 0.860  | 3.00                                     | 0.875  |
| 0.1347                           | 0.10   | 26                               | 0.9890 | 30  | 0.9870 | 12.50                                    | 0.960  | 10.75                            | 0.839  | 7.00                                     | 0.860  | 3.25                                     | 0.879  |
| 0.1436                           | 0.14   | 28                               | 0.9893 | 32  | 0.9872 | 12.75                                    | 0.965  | 11.00                            | 0.831  | 7.25                                     | 0.850  | 3.50                                     | 0.891  |
| 0.1570                           | 0.17   | 30                               | 0.9896 |   |        | 13.00                                    | 0.960  | 11.25                            | 0.841  | 7.50                                     | 0.879  | 3.75                                     | 0.898  |
| 0.1640                           | 0.20   | 32                               | 0.9898 |   |        | 13.25                                    | 0.950  | 11.50                            | 0.841  | 7.75                                     | 0.862  | 4.00                                     | 0.915  |
| 0.1857                           | 0.23   |                                  |        |   |        | 13.75                                    | 0.950  | 11.75                            | 0.840  | 8.00                                     | 0.870  | 4.25                                     | 0.890  |
| 0.1901                           | 0.29   |                                  |        |   |        | 14.00                                    | 0.935  | 12.00                            | 0.848  | 8.25                                     | 0.889  | 4.50                                     | 0.931  |
| 0.2026                           | 0.34   |                                  |        |   |        | 1.00                                     | 0.765  | 12.25                            | 0.845  | 8.50                                     | 0.891  | 4.75                                     | 0.910  |
|                                  |        |                                  |        |   |        | 1.25                                     | 0.810  | 12.50                            | 0.849  | 8.75                                     | 0.888  | 5.00                                     | 0.960  |
|                                  |        |                                  |        |   |        | 1.50                                     | 0.840  | 12.75                            | 0.845  | 9.00                                     | 0.899  | 5.25                                     | 0.915  |
|                                  |        |                                  |        |   |        | 1.75                                     | 0.860  | 13.25                            | 0.846  | 9.50                                     | 0.885  | 5.50                                     | 0.940  |
|                                  |        |                                  |        |   |        |  |        | 13.50                            | 0.842  | 9.75                                     | 0.898  | 5.75                                     | 0.925  |

\* Not shown on plot

DATA TABLE NO. 8 (continued)

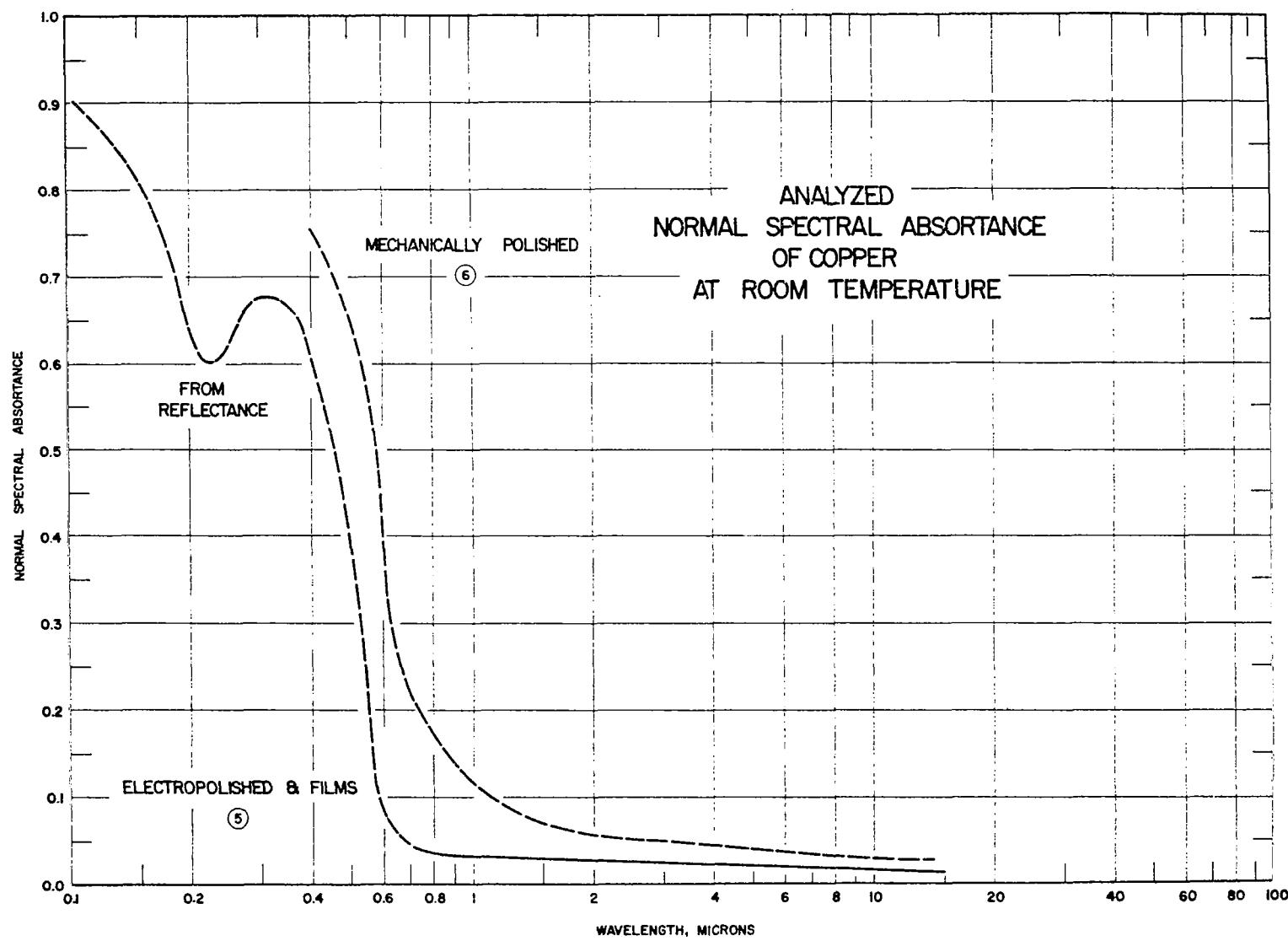
| $\lambda$              | $\rho$         | $\lambda$       | $\rho$         | $\lambda$               | $\rho$           | $\lambda$       | $\rho$          | $\lambda$        | $\rho$          | $\lambda$                | $\rho$          | $\lambda$        | $\rho$         |
|------------------------|----------------|-----------------|----------------|-------------------------|------------------|-----------------|-----------------|------------------|-----------------|--------------------------|-----------------|------------------|----------------|
| <u>CURVE 9 (cont.)</u> |                | <u>CURVE 12</u> |                | <u>CURVE 16 (cont.)</u> |                  | <u>CURVE 20</u> |                 | <u>CURVE 24*</u> |                 | <u>CURVE 24 (cont.)*</u> |                 | <u>CURVE 27*</u> |                |
|                        | <u>T = 300</u> |                 | <u>T = 298</u> |                         | <u>T = 298</u>   |                 | <u>T = 298</u>  |                  | <u>T = ~298</u> |                          | <u>T = ~298</u> |                  | <u>T = 298</u> |
| 6.00                   | 0.936          | 0.46            | 0.92           | 1.00                    | 0.93             | 2.01            | 0.960           | 1.01             | 0.929           | 13.01                    | 0.976           | 2.00             | 0.897          |
| 6.50                   | 0.930          | 0.53            | 0.92           | 1.25                    | 0.96             | 5.27            | 0.973           | 1.26             | 0.928           | 13.28                    | 0.976           | 4.00             | 0.918          |
| 6.75                   | 0.932          | 0.57            | 0.93           | 1.6                     | 0.98             | 7.94            | 0.979           | 1.50             | 0.944           | 13.50                    | 0.977           | 5.99             | 0.933          |
| 7.00                   | 0.942          | 0.60            | 0.93           | 1.8                     | 0.97             | 11.36           | 0.981           | 1.79             | 0.949           | 13.79                    | 0.976           | 8.00             | 0.945          |
| 7.25                   | 0.935          |                 |                | 2.2                     | 0.96             | 14.07           | 0.982           | 1.98             | 0.955           | 14.01                    | 0.976           | 10.00            | 0.954          |
| 8.00                   | 0.960          | <u>CURVE 13</u> |                | 2.3                     | 1.00             | 19.27           | 0.982           | 2.25             | 0.957           | 14.28                    | 0.977           | 12.00            | 0.952          |
| 8.25                   | 0.990          |                 | <u>T = 298</u> |                         |                  | 25.96           | 0.984           | 2.50             | 0.959           | 14.53                    | 0.973           | 14.00            | 0.954          |
| 8.75                   | 0.935          |                 |                |                         |                  |                 |                 | 2.75             | 0.955           | 14.75                    | 0.966           | 16.00            | 0.958          |
| 9.00                   | 0.960          | 0.46            | 0.895          |                         | <u>T = 298</u>   |                 |                 | 2.98             | 0.956           | 15.00                    | 0.971           | 18.00            | 0.958          |
| 9.25                   | 0.960          | 0.53            | 0.895          | 0.235                   | 0.413            | 1.57            | 0.890           | 3.27             | 0.964           |                          |                 | 20.00            | 0.955          |
| 9.50                   | 0.955          | 0.57            | 0.885          | 0.254                   | 0.482            | 4.34            | 0.929           | 3.50             | 0.955           |                          |                 | 22.00            | 0.946          |
| 9.75                   | 0.969          | 0.60            | 0.880          | 0.265                   | 0.523            | 4.34            | 0.929           | 3.76             | 0.963           |                          |                 | 23.99            | 0.946          |
| 10.00                  | 0.969          |                 |                |                         |                  |                 |                 | 3.96             | 0.974           |                          |                 |                  |                |
| 10.50                  | 0.975          | <u>CURVE 14</u> |                | 0.293                   | 0.662            | 7.17            | 0.946           | 4.24             | 0.940           | 1.97                     | 0.9670          | <u>CURVE 28</u>  |                |
| 10.75                  | 0.970          |                 | <u>T = 298</u> | 0.312                   | 0.679            | 8.53            | 0.946           | 4.48             | 0.968           | 2.97                     | 0.9712          |                  |                |
| 11.00                  | 0.972          |                 |                | 0.334                   | 0.722            | 11.73           | 0.953           | 4.76             | 0.969           | 3.95                     | 0.9747          |                  |                |
| 11.25                  | 0.972          | 2.00            | 0.970          | 0.366                   | 0.740            | 14.46           | 0.954           | 4.98             | 0.969           | 4.98                     | 0.9765          | 2.00             | 0.566          |
| 11.50                  | 0.959          | 10.00           | 0.970*         | 0.406                   | 0.712            | 17.38           | 0.961           | 5.24             | 0.972           | 6.00                     | 0.9774          | 4.00             | 0.676          |
| 11.75                  | 0.972          | 20.00           | 0.975          | 0.435                   | 0.759            | 19.33           | 0.961           | 5.50             | 0.969           | 7.03                     | 0.9778          | 5.99             | 0.731          |
| 12.00                  | 0.960          |                 |                | 0.546                   | 0.780            | 22.54           | 0.957           | 5.73             | 0.965           | 8.03                     | 0.9783          | 8.00             | 0.741          |
| 12.25                  | 0.960          | <u>CURVE 15</u> |                | 0.578                   | 0.781            | 25.94           | 0.952           | 5.98             | 0.977           | 9.00                     | 0.9790          | 10.00            | 0.757          |
| 12.50                  | 0.963          |                 | <u>T = 298</u> |                         |                  |                 |                 | 6.26             | 0.975           | 10.00                    | 0.9791          | 12.00            | 0.777          |
| 12.75                  | 0.959          |                 |                |                         |                  |                 |                 | 6.49             | 0.975           | 11.09                    | 0.9796          | 14.00            | 0.786          |
| 13.00                  | 0.980          | 0.20            | 0.90           |                         | <u>CURVE 18</u>  |                 | <u>T = 77</u>   | 6.74             | 0.971           | 12.04                    | 0.9798          | 16.00            | 0.789          |
| 13.25                  | 0.969          | 0.30            | 0.92           | 0.300                   | 0.671            | 1.91            | 0.908           | 6.98             | 0.969           | 13.05                    | 0.9805          | 18.00            | 0.790          |
| 13.50                  | 0.964          | 0.50            | 0.92           | 0.357                   | 0.706            | 3.95            | 0.939           | 7.26             | 0.969           |                          |                 | 20.00            | 0.792          |
| 13.75                  | 0.960          | 0.70            | 0.89           | 0.419                   | 0.733            | 5.94            | 0.937           | 7.51             | 0.970           |                          |                 | 22.00            | 0.792          |
| 14.00                  | 0.965          |                 |                |                         |                  |                 |                 | 7.76             | 0.976           |                          |                 |                  |                |
| 14.25                  | 0.951          | <u>CURVE 16</u> |                | 0.488                   | 0.753            | 7.90            | 0.945           | 7.98             | 0.974           |                          |                 |                  |                |
| 14.50                  | 0.969          |                 | <u>T = 298</u> | 0.538                   | 0.756            | 9.94            | 0.955           | 8.26             | 0.974           | 2.00                     | 0.964           | <u>CURVE 29*</u> |                |
| 14.75                  | 0.965          |                 |                | 0.579                   | 0.754            | 11.97           | 0.952           | 8.53             | 0.978           | 4.00                     | 0.970           |                  |                |
| 15.00                  | 0.972          | 0.225           | 0.79           | 0.627                   | 0.751            | 13.88           | 0.953           | 8.78             | 0.968           | 5.99                     | 0.973           | 0.0790           | 0.325          |
|                        |                | 0.250           | 0.80           | 0.752                   | 0.751            | 15.89           | 0.959           | 9.00             | 0.967           | 8.00                     | 0.977           | 0.0833           | 0.624          |
|                        |                |                 |                |                         |                  |                 |                 |                  |                 |                          |                 |                  |                |
|                        |                | <u>CURVE 10</u> |                | 0.275                   | 0.81             | 0.871           | 0.747           | 17.92            | 0.962           | 9.29                     | 0.972           | 10.00            | 0.980          |
|                        |                |                 |                | 0.300                   | 0.83             | 1.000           | 0.738           | 19.94            | 0.960           | 9.55                     | 0.971           | 12.00            | 0.981          |
|                        |                |                 |                | 0.325                   | 0.84             |                 |                 | 21.86            | 0.957           | 9.79                     | 0.974           | 14.00            | 0.980          |
| 0.46                   | 0.89           | 0.350           | 0.85           |                         | <u>CURVE 19*</u> | 23.93           | 0.949           | 10.01            | 0.973           | 16.00                    | 0.980           | <u>CURVE 30*</u> |                |
| 0.53                   | 0.89           | 0.375           | 0.86           |                         |                  | 26.00           | 0.949           | 10.27            | 0.973           | 18.00                    | 0.980           |                  |                |
| 0.57                   | 0.90           | 0.400           | 0.86           |                         |                  |                 |                 | 10.53            | 0.973           | 20.00                    | 0.979           |                  |                |
| 0.60                   | 0.90           | 0.450           | 0.87           | 0.450                   | 0.9083           |                 | <u>CURVE 23</u> | 10.77            | 0.973           | 22.00                    | 0.979           | 0.0790           | 0.308          |
|                        |                | 0.500           | 0.88           | 0.500                   | 0.9082           |                 |                 | 11.04            | 0.973           | 23.99                    | 0.978           | 0.0833           | 0.588          |
|                        |                |                 |                |                         |                  |                 |                 |                  |                 |                          |                 | 0.0920           | 0.728          |
|                        |                | <u>CURVE 11</u> |                | 0.600                   | 0.89             | 0.550           | 0.9064          |                  |                 |                          |                 | 0.1175           | 0.811          |
|                        |                |                 |                | 0.75                    | 0.88             | 0.600           | 0.9026          | 0.2653           | 0.756           | 11.30                    | 0.974           |                  |                |
| 0.46                   | 0.86           | 0.8             | 0.85           |                         |                  | 0.2890          | 0.796           | 11.52            | 0.976           | 11.78                    | 0.976           |                  |                |
| 0.53                   | 0.86           | 0.85            | 0.87           |                         |                  |                 |                 |                  |                 | 12.02                    | 0.976           |                  |                |
| 0.57                   | 0.85           | 0.9             | 0.88           |                         |                  |                 |                 |                  |                 | 12.27                    | 0.977           |                  |                |
| 0.60                   | 0.86           | 0.95            | 0.94           |                         |                  |                 |                 |                  |                 | 12.51                    | 0.974           |                  |                |
|                        |                |                 |                |                         |                  |                 |                 |                  |                 | 12.79                    | 0.976           |                  |                |

\* Not shown on plot

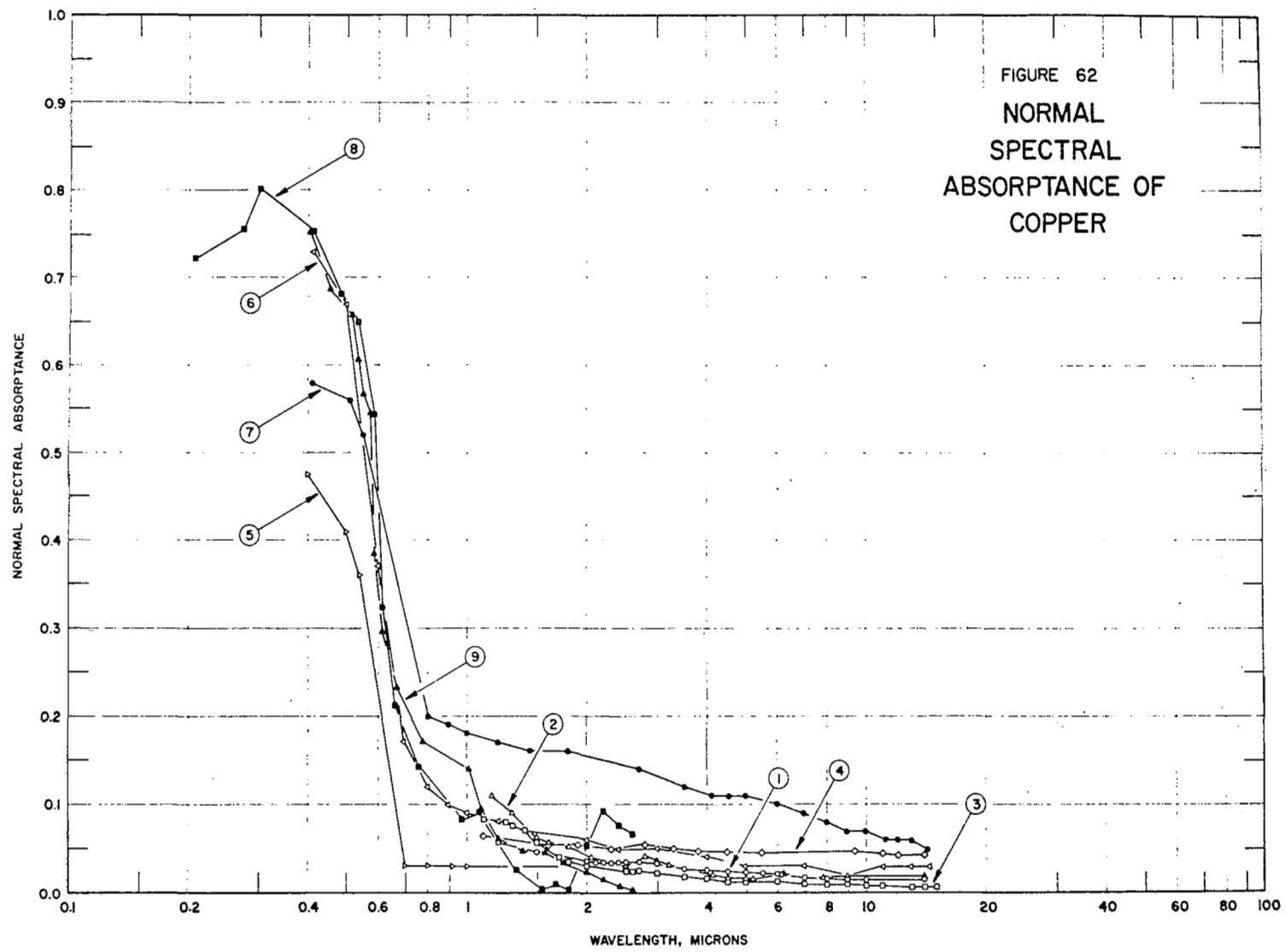
DATA TABLE NO. 8 (continued)

| $\lambda$                          | $\rho$ | $\lambda$                         | $\rho$ | $\lambda$                         | $\sigma$ | $\lambda$                          | $\sigma$ | $\lambda$                                  | $\sigma$ | $\lambda$                         | $\rho$ |
|------------------------------------|--------|-----------------------------------|--------|-----------------------------------|----------|------------------------------------|----------|--|----------|-----------------------------------|--------|
| <u>CURVE 31*</u><br><u>T = 298</u> |        | <u>CURVE 35</u><br><u>T = 298</u> |        | <u>CURVE 37 (cont.)</u>           |          | <u>CURVE 39*</u><br><u>T = 298</u> |          | <u>CURVE 40 (cont.)*</u><br><u>T = 298</u> |          | <u>CURVE 43</u><br><u>T = 298</u> |        |
| 0.0790                             | 0.292  | 7.07                              | 0.083  | 10.03                             | 0.537    | 0.64                               | 0.027    | 21.23                                      | 0.876    | 2.49                              | 0.033  |
| 0.0833                             | 0.559  | 8.04                              | 0.140  | 11.07                             | 0.602    | 0.77                               | 0.077    | 22.23                                      | 0.892    | 3.09                              | 0.077  |
| 0.0920                             | 0.689  | 9.06                              | 0.206  | 12.08                             | 0.660    | 0.97                               | 0.126    |  |          | 4.07                              | 0.225  |
| 0.1175                             | 0.811  | 10.04                             | 0.272  | 13.08                             | 0.703    | 1.07                               | 0.172    | <u>CURVE 41*</u><br><u>T = 298</u>         |          | 5.06                              | 0.382  |
|                                    |        | 11.04                             | 0.337  | 14.07                             | 0.738    | 1.56                               | 0.412    |  |          | 6.08                              | 0.509  |
| <u>CURVE 32*</u><br><u>T = 298</u> |        | 12.01                             | 0.409  | 15.26                             | 0.777    | 2.08                               | 0.575    |  |          | 7.08                              | 0.611  |
|                                    |        | 13.00                             | 0.456  | 16.12                             | 0.803    | 3.11                               | 0.752    | 3.88                                       | 0.014    | 8.07                              | 0.683  |
|                                    |        | 14.06                             | 0.509  | 17.10                             | 0.820    | 4.08                               | 0.845    | 5.03                                       | 0.107    | 9.13                              | 0.753  |
| 0.0790                             | 0.276  | 15.25                             | 0.565  | 18.10                             | 0.840    | 5.07                               | 0.592    | 6.01                                       | 0.197    | 10.11                             | 0.789  |
| 0.0833                             | 0.528  | 16.07                             | 0.597  | 19.10                             | 0.859    | 6.05                               | 0.919    | 7.01                                       | 0.292    | 11.09                             | 0.824  |
| 0.0920                             | 0.653  | 17.07                             | 0.634  | 20.13                             | 0.877    | 7.10                               | 0.942    | 8.03                                       | 0.380    | 12.10                             | 0.855  |
| 0.1175                             | 0.811* | 18.05                             | 0.668  | 21.14                             | 0.891    | 8.10                               | 0.956    | 9.03                                       | 0.467    | 13.07                             | 0.874  |
|                                    |        | 19.07                             | 0.694  | 22.12                             | 0.902    | 9.09                               | 0.965    | 10.03                                      | 0.531    | 14.10                             | 0.890  |
| <u>CURVE 33</u><br><u>T = 298</u>  |        | 20.12                             | 0.728  |                                   |          | 10.09                              | 0.970    | 11.07                                      | 0.597    | 15.35                             | 0.910  |
|                                    |        | 21.12                             | 0.755  | <u>CURVE 38</u><br><u>T = 298</u> |          | 11.08                              | 0.974    | 12.12                                      | 0.655    | 16.16                             | 0.918  |
|                                    |        | 22.10                             | 0.788  |                                   |          | 12.09                              | 0.980    | 13.07                                      | 0.694    | 17.13                             | 0.930  |
| 2.47                               | 0.033  |                                   |        |                                   |          | 13.11                              | 0.983    | 14.12                                      | 0.733    | 18.18                             | 0.939  |
| 2.99                               | 0.082  | <u>CURVE 36</u><br><u>T = 298</u> |        | 0.63                              | 0.025    | 14.12                              | 0.986    | 15.30                                      | 0.769    | 19.17                             | 0.946  |
| 3.97                               | 0.230  |                                   |        | 0.87                              | 0.079    | 15.08                              | 0.989    | 16.13                                      | 0.795    | 20.25                             | 0.952  |
| 4.98                               | 0.388  |                                   |        | 0.99                              | 0.126    | 16.15                              | 0.993    | 17.12                                      | 0.814    | 21.23                             | 0.960  |
| 6.00                               | 0.515  | 5.08                              | 0.079  | 1.08                              | 0.168    | 17.13                              | 0.993    | 18.16                                      | 0.832    | 22.21                             | 0.967  |
| 7.00                               | 0.615  | 6.07                              | 0.161  | 1.49                              | 0.277    | 18.13                              | 0.993    | 19.17                                      | 0.853    |                                   |        |
| 8.02                               | 0.692  | 7.08                              | 0.250  | 2.09                              | 0.398    | 19.11                              | 0.994    | 20.20                                      | 0.872    |                                   |        |
| 9.00                               | 0.760  | 8.06                              | 0.339  | 3.06                              | 0.548    | 20.16                              | 0.994    | 21.25                                      | 0.886    |                                   |        |
| 10.04                              | 0.797  | 9.03                              | 0.428  | 4.06                              | 0.661    | 21.15                              | 0.994    | 22.25                                      | 0.898    |                                   |        |
| 11.04                              | 0.831* | 10.08                             | 0.492  | 5.07                              | 0.738    | 22.14                              | 0.998    |  |          |                                   |        |
| 12.08                              | 0.857  | 11.04                             | 0.559  | 6.07                              | 0.801*   | <u>CURVE 40*</u><br><u>T = 298</u> |          | <u>CURVE 42</u><br><u>T = 298</u>          |          |                                   |        |
|                                    |        | 12.08                             | 0.617  | 7.04                              | 0.841    |                                    |          |  |          |                                   |        |
| <u>CURVE 34</u><br><u>T = 298</u>  |        | 13.06                             | 0.656  | 8.06                              | 0.873    |                                    |          |  |          |                                   |        |
|                                    |        | 14.10                             | 0.699  | 9.10                              | 0.896    |                                    |          |  |          |                                   |        |
|                                    |        | 15.34                             | 0.738  | 10.01                             | 0.911    | 3.93                               | 0.005    | 4.06                                       | 0.119    |                                   |        |
| 0.52                               | 0.065  | 16.12                             | 0.759  | 11.06                             | 0.926    | 5.05                               | 0.095    | 5.03                                       | 0.243    |                                   |        |
| 0.71                               | 0.063  | 17.03                             | 0.782  | 12.06                             | 0.939    | 6.03                               | 0.190    | 7.05                                       | 0.479    |                                   |        |
| 0.89                               | 0.060  | 18.04                             | 0.802  | 13.12                             | 0.953    | 7.01                               | 0.284    | 8.02                                       | 0.564    |                                   |        |
| 1.47                               | 0.075  | 19.07                             | 0.823  | 14.12                             | 0.958    | 8.02                               | 0.373    | 9.07                                       | 0.646    |                                   |        |
| 2.00                               | 0.093  | 20.13                             | 0.846  | 15.08                             | 0.963    | 9.02                               | 0.452    | 10.05                                      | 0.694    |                                   |        |
| 2.99                               | 0.163  | 21.16                             | 0.864  | 16.10                             | 0.969    | 10.03                              | 0.524    | 11.10                                      | 0.738    |                                   |        |
| 3.99                               | 0.270  | 22.19                             | 0.883  | 17.08                             | 0.972    | 11.02                              | 0.588    | 12.09                                      | 0.781    |                                   |        |
| 4.99                               | 0.398  |                                   |        | 18.09                             | 0.974    | 12.09                              | 0.649    | 13.08                                      | 0.807    |                                   |        |
| 6.00                               | 0.513  | <u>CURVE 37</u><br><u>T = 298</u> |        | 19.13                             | 0.978    | 13.10                              | 0.684    | 14.14                                      | 0.833    |                                   |        |
| 7.00                               | 0.612  |                                   |        | 20.18                             | 0.981    | 14.10                              | 0.722    | 15.32                                      | 0.856    |                                   |        |
| 8.01                               | 0.688  |                                   |        | 21.12                             | 0.981    | 15.28                              | 0.762    | 16.13                                      | 0.867    |                                   |        |
| 9.02                               | 0.746  | 5.07                              | 0.108  | 22.11                             | 0.989    | 16.15                              | 0.783    | 17.17                                      | 0.883    |                                   |        |
| 10.03                              | 0.784  | 6.02                              | 0.197  |                                   |          | 17.11                              | 0.806    | 18.24                                      | 0.897    |                                   |        |
| 11.06                              | 0.822  | 7.05                              | 0.294  |                                   |          | 18.17                              | 0.829    | 19.16                                      | 0.908    |                                   |        |
| 12.07                              | 0.849  | 8.05                              | 0.384  |                                   |          | 19.20                              | 0.845    | 20.22                                      | 0.918    |                                   |        |
|                                    |        |                                   |        |                                   |          |                                    |          | 21.22                                      | 0.927    |                                   |        |
|                                    |        |                                   |        |                                   |          |                                    |          | 22.23                                      | 0.939    |                                   |        |

\* Not shown on plot



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## SPECIFICATION TABLE NO. 62 NORMAL SPECTRAL ABSORPTANCE OF COPPER

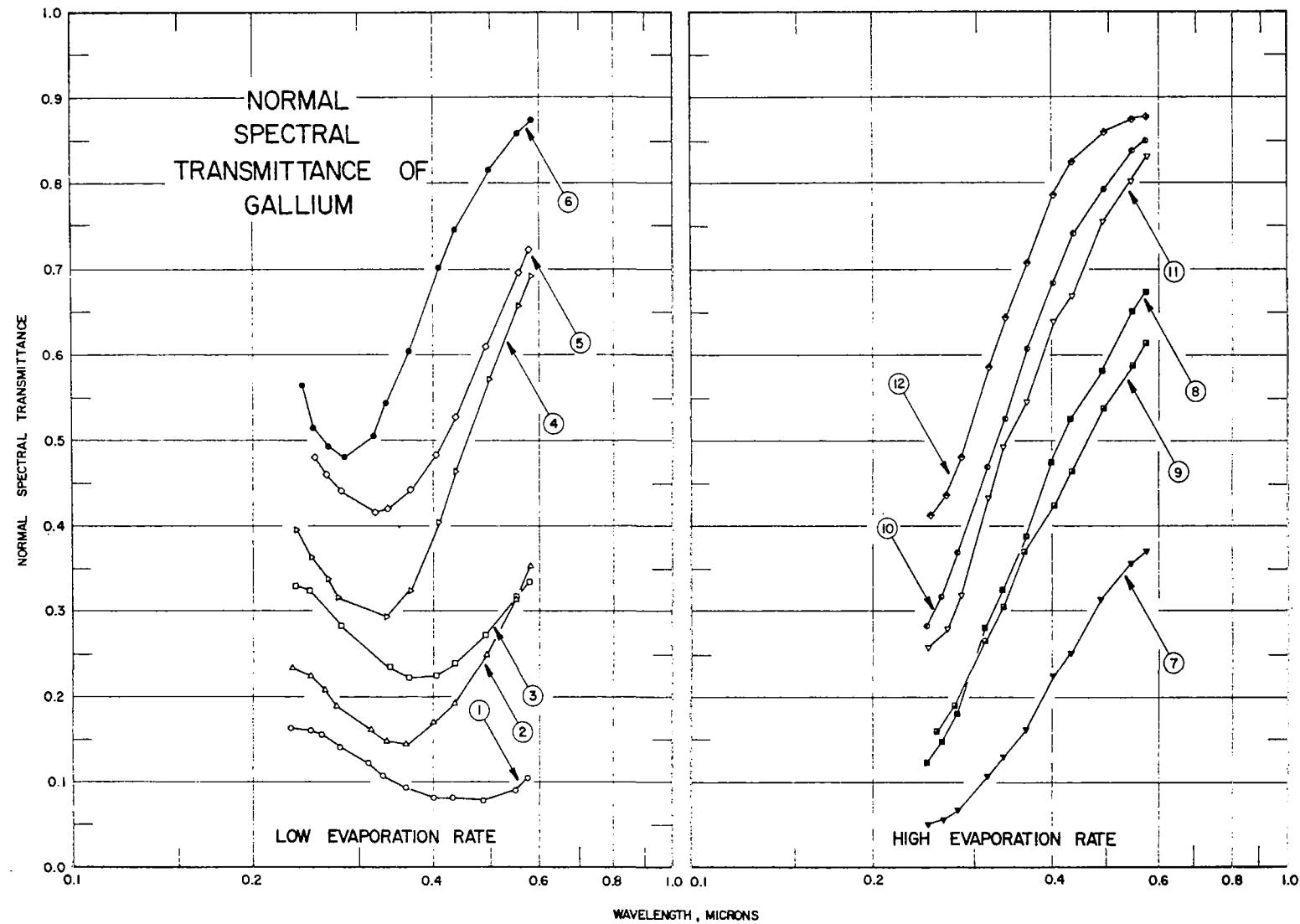
| Curve No. | Ref. No. | Year | Temperature K | Wavelength Range, $\mu$ | Geometry $\theta$ | Reported Error, % | Composition (weight percent), Specifications and Remarks  |
|-----------|----------|------|---------------|-------------------------|-------------------|-------------------|---|
| 1         | 30       | 1963 | 294           | 1.20-14.00              | $\sim 0^\circ$    |                   | Mechanically polished (surface roughness $0.02\mu$ peak to peak and $5\mu$ lateral); measured in air; data extracted from smooth curve; [Author's designation: Sample 3]. |
| 2         | 30       | 1963 | 294           | 1.15-14.00              | $\sim 0^\circ$    |                   | Above specimen and conditions except heated at 450 K for 3 hrs; surface oxidation possible.   |
| 3         | 30       | 1963 | 294           | 1.10-15.00              | $\sim 0^\circ$    |                   | Above specimen and conditions except heated at 922 K for 3 hrs.   |
| 4         | 30       | 1963 | 294           | 1.10-14.00              | $\sim 0^\circ$    |                   | Above specimen and conditions except heated at 1222 K for 102 hrs.  |
| 5         | 65       | 1962 | 294           | 0.40-2.00               | $\sim 0^\circ$    |                   | Electropolished; calculated from $(1 - \rho)$ .   |
| 6         | 65       | 1962 | 294           | 0.41-14.40              | $\sim 0^\circ$    |                   | Mechanically polished; calculated from $(1 - \rho)$ .   |
| 7         | 65       | 1962 | 294           | 0.41-14.20              | $\sim 0^\circ$    |                   | Above specimen and conditions except roughened with sand paper; surface roughness $1.25\mu$ .   |
| 8         | 307      | 1954 | $\sim 298$    | 0.207-2.600             | $\sim 0^\circ$    |                   | Data extracted from smooth curve.   |
| 9         | 307      | 1954 | $\sim 298$    | 0.401-2.600             | $\sim 0^\circ$    |                   | Polished; data extracted from smooth curve.   |

## DATA TABLE NO. 62 NORMAL SPECTRAL ABSORPTANCE OF COPPER

[Wavelength,  $\lambda \mu$ ; Absorptance,  $\alpha$ ; Temperature, T,K]

| $\lambda$      | $\alpha$ | $\lambda$              | $\alpha$ | $\lambda$              | $\alpha$ | $\lambda$      | $\alpha$ | $\lambda$              | $\alpha$ |       |
|----------------|----------|------------------------|----------|------------------------|----------|----------------|----------|------------------------|----------|-------|
| <u>CURVE 1</u> |          | <u>CURVE 2 (cont.)</u> |          | <u>CURVE 4 (cont.)</u> |          | <u>CURVE 7</u> |          | <u>CURVE 8 (cont.)</u> |          |       |
|                | T = 294  |                        |          |                        |          | T = 294        |          |                        |          |       |
| 1.20           | 0.057    | 6.20                   | 0.021    | 3.30                   | 0.050    | 0.41           | 0.58     | 2.000                  | 0.053    |       |
| 1.50           | 0.046    | 7.00                   | 0.019*   | 3.80                   | 0.048    | 0.51           | 0.56     | 2.200                  | 0.091    |       |
| 2.00           | 0.036    | 7.80                   | 0.018    | 4.50                   | 0.047    | 0.55           | 0.52     | 2.400                  | 0.075    |       |
| 2.10           | 0.034    | 9.00                   | 0.018    | 5.50                   | 0.046    | 0.80           | 0.20     | 2.600                  | 0.067    |       |
| 2.20           | 0.034    | 14.00                  | 0.019    | 9.40                   | 0.048    | 11.00          | 0.044    | 0.90                   | 0.19     |       |
| 2.30           | 0.033    |                        |          |                        |          | 12.00          | 0.043    | 1.00                   | 0.18     |       |
| 2.40           | 0.034    |                        | T = 294  |                        | 14.00    | 0.043          |          | 1.20                   | 0.17     |       |
| 2.50           | 0.035    |                        |          |                        |          |                |          | 1.44                   | 0.16     |       |
| 2.70           | 0.035    | 1.10                   | 0.082    |                        |          |                |          | 1.80                   | 0.16     |       |
| 3.00           | 0.033    | 1.25                   | 0.080    |                        |          |                |          | 2.70                   | 0.14     |       |
| 3.50           | 0.028    | 1.30                   | 0.076    |                        |          |                |          | 3.50                   | 0.12     |       |
| 4.00           | 0.027    | 1.40                   | 0.070    |                        |          |                |          | 4.05                   | 0.11     |       |
| 4.50           | 0.025    | 1.50                   | 0.057    |                        |          |                |          | 4.55                   | 0.11     |       |
| 5.00           | 0.023    | 1.70                   | 0.040    |                        |          |                |          | 5.00                   | 0.11     |       |
| 5.50           | 0.022    | 1.80                   | 0.035    |                        |          |                |          | 6.00                   | 0.10     |       |
| 6.00           | 0.021    | 2.00                   | 0.031    |                        |          |                |          | 7.00                   | 0.09     |       |
| 6.10           | 0.021    | 2.50                   | 0.024    |                        |          |                |          | 8.00                   | 0.08     |       |
| 7.00           | 0.018    | 2.60                   | 0.024    |                        |          |                |          | 9.00                   | 0.07     |       |
| 8.00           | 0.017    | 2.70                   | 0.025    |                        |          |                |          | 10.00                  | 0.07     |       |
| 9.00           | 0.015    | 3.00                   | 0.022    |                        |          |                |          | 11.20                  | 0.06     |       |
| 10.00          | 0.015    | 3.50                   | 0.019    |                        |          |                |          | 12.00                  | 0.06     |       |
| 14.00          | 0.015    | 4.00                   | 0.016    |                        |          |                |          | 13.00                  | 0.06     |       |
|                |          |                        |          |                        |          |                |          | 14.20                  | 0.05     |       |
| <u>CURVE 2</u> |          | 5.00                   | 0.012    | 0.41                   | 0.73     |                |          |                        | 1.798    | 0.034 |
|                | T = 294  | 6.00                   | 0.012    | 0.50                   | 0.67     |                |          |                        | 2.000    | 0.023 |
|                |          | 7.00                   | 0.011    | 0.60                   | 0.37     |                |          |                        | 2.200    | 0.014 |
| 1.15           | 0.110    | 8.00                   | 0.010    | 0.70                   | 0.17     |                |          |                        | 2.400    | 0.008 |
| 1.30           | 0.090    | 9.00                   | 0.009    | 0.80                   | 0.12     |                |          |                        | 2.600    | 0.023 |
| 1.50           | 0.062    | 10.00                  | 0.008    | 0.90                   | 0.10     |                |          |                        |          |       |
| 1.60           | 0.057    | 11.00                  | 0.008    | 1.00                   | 0.09     |                |          |                        |          |       |
| 1.80           | 0.051    | 13.00                  | 0.007    | 1.20                   | 0.08     |                |          |                        |          |       |
| 2.05           | 0.040    | 14.00                  | 0.007    | 1.40                   | 0.07*    |                |          |                        |          |       |
| 2.30           | 0.032*   | 15.00                  | 0.007    | 2.00                   | 0.06     |                |          |                        |          |       |
| 2.50           | 0.031    |                        |          | 2.40                   | 0.05     |                |          |                        |          |       |
| 2.80           | 0.041    |                        |          | 3.00                   | 0.05     |                |          |                        |          |       |
| 3.00           | 0.035    |                        | T = 294  | 4.00                   | 0.04     |                |          |                        |          |       |
| 3.20           | 0.031    |                        |          | 5.00                   | 0.03     |                |          |                        |          |       |
| 3.50           | 0.028*   | 1.10                   | 0.064    | 7.00                   | 0.03     |                |          |                        |          |       |
| 4.10           | 0.020    | 1.50                   | 0.055*   | 9.00                   | 0.02*    |                |          |                        |          |       |
| 4.50           | 0.017    | 1.60                   | 0.054    | 11.00                  | 0.03     |                |          |                        |          |       |
| 5.00           | 0.016    | 1.90                   | 0.054    | 13.00                  | 0.03     |                |          |                        |          |       |
| 5.20           | 0.016    | 2.30                   | 0.050    | 14.40                  | 0.03     |                |          |                        |          |       |
| 6.00           | 0.020*   | 2.80                   | 0.055    |                        |          |                |          | 1.688                  | 0.010    |       |
|                |          |                        |          |                        |          |                |          | 1.801                  | 0.003    |       |

# Not shown on plot



SPECIFICATION TABLE NO. 73 NORMAL SPECTRAL TRANSMITTANCE OF GALLIUM

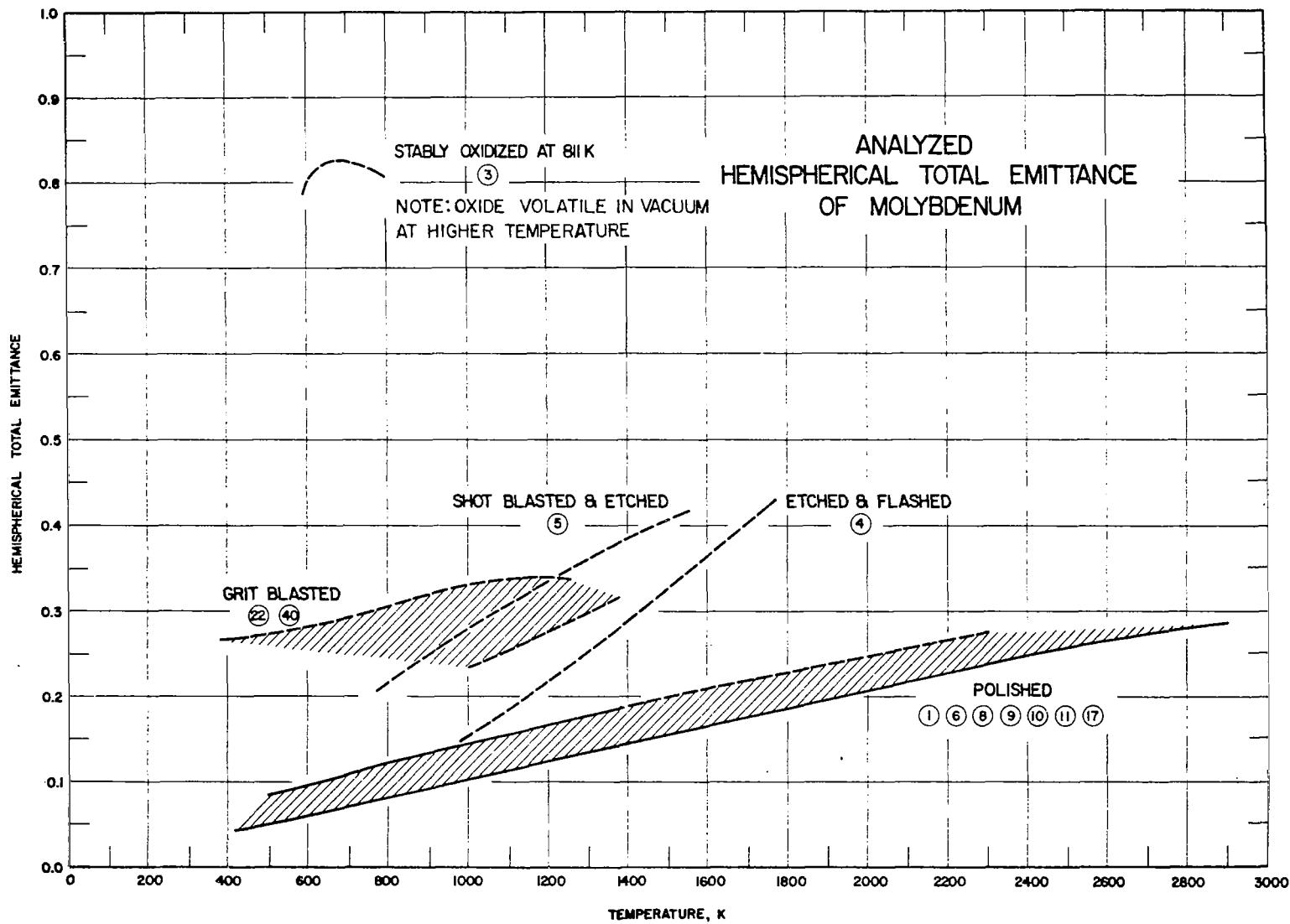
| Curve No. | Ref. No. | Year | Temperature K | Wavelength Range, $\mu$ | Geometry<br>$\theta$ $\theta'$ $\omega'$ | Reported Error, % | Composition (weight percent), Specifications and Remarks  |
|-----------|----------|------|---------------|-------------------------|--|-------------------|---|
| 1         | 229      | 1963 | 298           | 0.231-0.574             | $\sim 0^\circ$ $\sim 0^\circ$            |                   | Vacuum deposited thin film of gallium (19 m $\mu$ thick); measured in vacuum; spectral Philips Zn, Cd and Hg Lamp sources; 3.5 Å min $^{-1}$ evaporation rate.            |
| 2         | 229      | 1963 | 298           | 0.233-0.579             | $\sim 0^\circ$ $\sim 0^\circ$            |                   | Different sample, same as above specimen and conditions except 11 m $\mu$ thick; 2 Å min $^{-1}$ evaporation rate.  |
| 3         | 229      | 1963 | 298           | 0.236-0.576             | $\sim 0^\circ$ $\sim 0^\circ$            |                   | Different sample, same as above specimen and conditions except 9.5 m $\mu$ thick.   |
| 4         | 229      | 1963 | 298           | 0.236-0.581             | $\sim 0^\circ$ $\sim 0^\circ$            |                   | Different sample, same as above specimen and conditions except 5 m $\mu$ thick; 2 Å min $^{-1}$ evaporation rate.   |
| 5         | 229      | 1963 | 298           | 0.242-0.577             | $\sim 0^\circ$ $\sim 0^\circ$            |                   | Different sample, same as above specimen and conditions except 4.5 m $\mu$ thick.   |
| 6         | 229      | 1963 | 298           | 0.242-0.584             | $\sim 0^\circ$ $\sim 0^\circ$            |                   | Different sample, same as above specimen and conditions except 2.5 m $\mu$ thick; 2 Å min $^{-1}$ evaporation rate.   |
| 7         | 229      | 1963 | 298           | 0.250-0.579             | $\sim 0^\circ$ $\sim 0^\circ$            |                   | Different sample, same as above specimen and conditions except 42 m $\mu$ thick; 300 Å min $^{-1}$ evaporation rate; supercooled liquid suspected in the evaporated film. |
| 8         | 229      | 1963 | 298           | 0.248-0.578             | $\sim 0^\circ$ $\sim 0^\circ$            |                   | Different sample, same as curve 7 specimen and conditions except 28 m $\mu$ thick; 11 Å min $^{-1}$ evaporation rate.   |
| 9         | 229      | 1963 | 298           | 0.258-0.579             | $\sim 0^\circ$ $\sim 0^\circ$            |                   | Different sample, same as curve 7 specimen and conditions except 21 m $\mu$ thick.  |
| 10        | 229      | 1963 | 298           | 0.247-0.579             | $\sim 0^\circ$ $\sim 0^\circ$            |                   | Different sample, same as curve 7 specimen and conditions except 14 m $\mu$ thick; 11 Å min $^{-1}$ evaporation rate.   |
| 11        | 229      | 1963 | 298           | 0.249-0.581             | $\sim 0^\circ$ $\sim 0^\circ$            |                   | Different sample, same as curve 7 specimen and conditions except 10 m $\mu$ thick.  |
| 12        | 229      | 1963 | 298           | 0.252-0.581             | $\sim 0^\circ$ $\sim 0^\circ$            |                   | Different sample, same as curve 7 specimen and conditions except 7 m $\mu$ thick; 11 Å min $^{-1}$ evaporation rate.  |

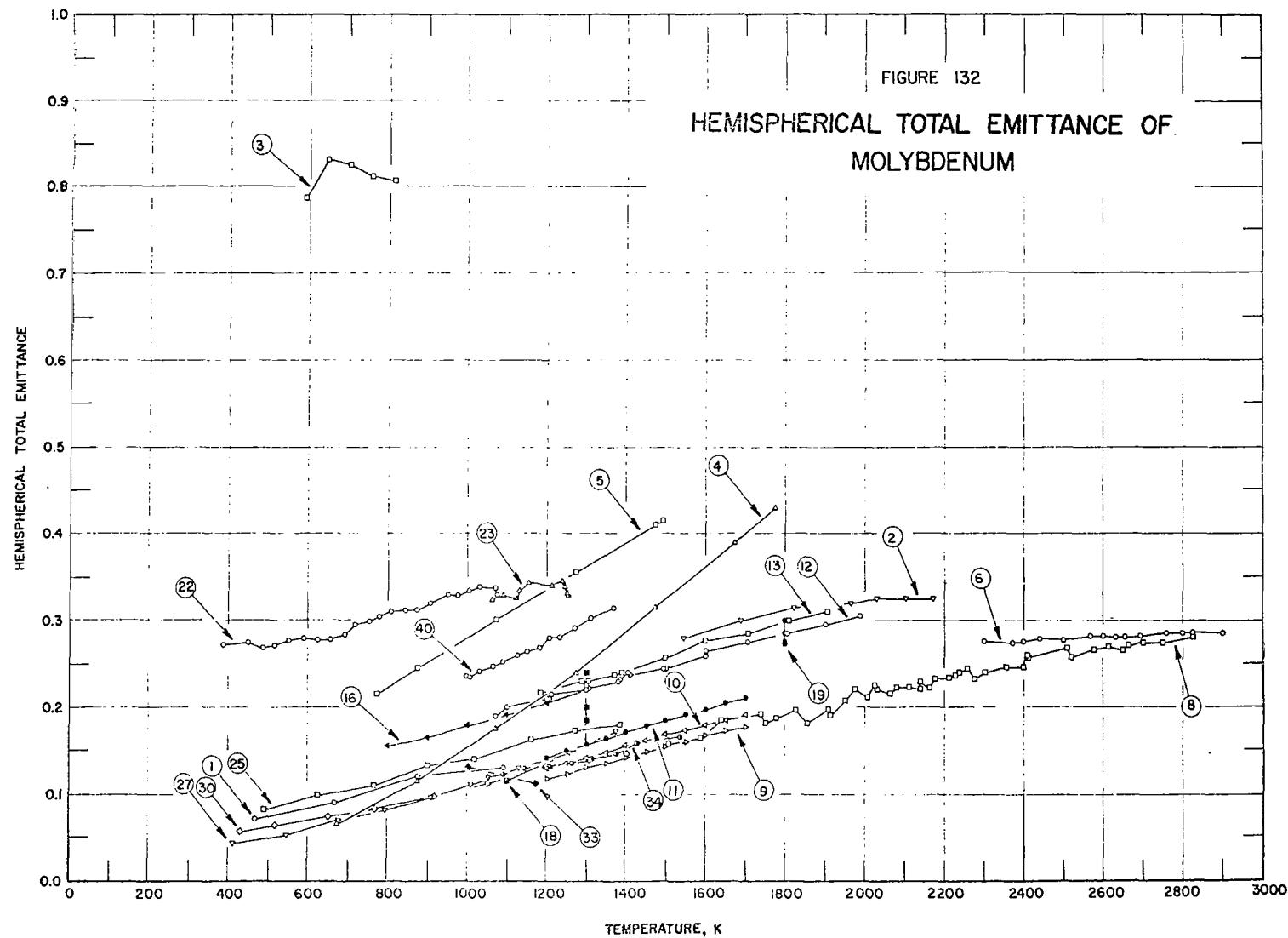
## DATA TABLE NO. 73 NORMAL SPECTRAL TRANSMITTANCE OF GALLIUM

{Temperature, T, K; Transmittance, τ; Wavelength, λ, μ}

| $\lambda$                 | $\tau$ | $\lambda$                 | $\tau$ | $\lambda$                 | $\tau$ | $\lambda$                  | $\tau$ |
|---------------------------|--------|---------------------------|--------|---------------------------|--------|----------------------------|--------|
| <u>CURVE 1</u><br>T = 298 |        | <u>CURVE 4</u><br>T = 298 |        | <u>CURVE 7</u><br>T = 298 |        | <u>CURVE 10</u><br>T = 298 |        |
| 0.231                     | 0.162  | 0.236                     | 0.396  | 0.250                     | 0.050  | 0.247                      | 0.282  |
| 0.249                     | 0.160  | 0.250                     | 0.362  | 0.265                     | 0.057  | 0.262                      | 0.318  |
| 0.261                     | 0.155  | 0.267                     | 0.338  | 0.280                     | 0.068  | 0.278                      | 0.369  |
| 0.278                     | 0.140  | 0.277                     | 0.317  | 0.313                     | 0.107  | 0.314                      | 0.468  |
| 0.311                     | 0.122  | 0.333                     | 0.294  | 0.333                     | 0.130  | 0.336                      | 0.525  |
| 0.329                     | 0.107  | 0.365                     | 0.324  | 0.364                     | 0.161  | 0.367                      | 0.607  |
| 0.359                     | 0.094  | 0.408                     | 0.404  | 0.405                     | 0.224  | 0.405                      | 0.684  |
| 0.401                     | 0.081  | 0.435                     | 0.463  | 0.432                     | 0.251  | 0.438                      | 0.741  |
| 0.430                     | 0.081  | 0.495                     | 0.572  | 0.487                     | 0.314  | 0.494                      | 0.794  |
| 0.484                     | 0.078  | 0.551                     | 0.658  | 0.548                     | 0.356  | 0.550                      | 0.838  |
| 0.547                     | 0.091  | 0.581                     | 0.693  | 0.579                     | 0.370  | 0.579                      | 0.851  |
| 0.574                     | 0.105  |                           |        |                           |        |                            |        |
| <u>CURVE 2</u><br>T = 298 |        | <u>CURVE 5</u><br>T = 298 |        | <u>CURVE 8</u><br>T = 298 |        | <u>CURVE 11</u><br>T = 298 |        |
| 0.233                     | 0.233  | 0.242                     | 0.504  | 0.248                     | 0.122  | 0.249                      | 0.257  |
| 0.250                     | 0.224  | 0.253                     | 0.481  | 0.262                     | 0.147  | 0.268                      | 0.279  |
| 0.263                     | 0.207  | 0.265                     | 0.459  | 0.279                     | 0.180  | 0.283                      | 0.318  |
| 0.276                     | 0.189  | 0.279                     | 0.441  | 0.311                     | 0.280  | 0.315                      | 0.432  |
| 0.314                     | 0.161  | 0.319                     | 0.414  | 0.332                     | 0.325  | 0.334                      | 0.492  |
| 0.333                     | 0.148  | 0.336                     | 0.420  | 0.364                     | 0.388  | 0.365                      | 0.544  |
| 0.360                     | 0.144  | 0.366                     | 0.442  | 0.402                     | 0.473  | 0.406                      | 0.639  |
| 0.402                     | 0.170  | 0.436                     | 0.527  | 0.490                     | 0.582  | 0.493                      | 0.755  |
| 0.434                     | 0.193  | 0.490                     | 0.610  | 0.549                     | 0.651  | 0.549                      | 0.802  |
| 0.490                     | 0.250  | 0.557                     | 0.697  | 0.578                     | 0.673  | 0.581                      | 0.833  |
| 0.549                     | 0.313  | 0.577                     | 0.722  |                           |        |                            |        |
| 0.579                     | 0.352  |                           |        | <u>CURVE 9</u><br>T = 298 |        | <u>CURVE 12</u><br>T = 298 |        |
| <u>CURVE 3</u><br>T = 298 |        | <u>CURVE 6</u><br>T = 298 |        | 0.258                     | 0.158  | 0.252                      | 0.412  |
| 0.236                     | 0.330  | 0.242                     | 0.564  | 0.275                     | 0.190  | 0.268                      | 0.437  |
| 0.248                     | 0.324  | 0.253                     | 0.515  | 0.311                     | 0.264  | 0.284                      | 0.482  |
| 0.280                     | 0.282  | 0.267                     | 0.493  | 0.333                     | 0.303  | 0.317                      | 0.587  |
| 0.337                     | 0.234  | 0.284                     | 0.481  | 0.362                     | 0.370  | 0.336                      | 0.644  |
| 0.364                     | 0.222  | 0.318                     | 0.505  | 0.406                     | 0.424  | 0.366                      | 0.708  |
| 0.405                     | 0.225  | 0.334                     | 0.544  | 0.434                     | 0.462  | 0.407                      | 0.787  |
| 0.433                     | 0.239  | 0.364                     | 0.604  | 0.491                     | 0.538  | 0.436                      | 0.825  |
| 0.489                     | 0.272  | 0.409                     | 0.701  | 0.550                     | 0.589  | 0.496                      | 0.860  |
| 0.549                     | 0.316  | 0.435                     | 0.747  | 0.579                     | 0.614  | 0.551                      | 0.875  |
| 0.578                     | 0.335  | 0.497                     | 0.818  | 0.554                     | 0.860  | 0.581                      | 0.879  |
|                           |        | 0.584                     | 0.875  |                           |        |                            |        |







SPECIFICATION TABLE NO. 132 HEMISPHERICAL TOTAL EMITTANCE OF MOLYBDENUM

| Curve No. | Ref. No. | Year | Temperature Range, K | Reported Error, % | Composition (weight percent), Specifications and Remarks  |
|-----------|----------|------|----------------------|-------------------|---|
| 1         | 47       | 1961 | 468-1093             | <10               | Vacuum arc cast, machined, extruded, recrystallized, rolled; disc (0.04 in. thick); ground with 600 grit carborundum and polished on a wet cloth lap with unlevigated jewelers rouge; measured in vacuum ( $10^{-5}$ mm Hg).                          |
| 2         | 69       | 1960 | 1544-2172            | $\pm$ 10          | Measured in vacuum.   |
| 3         | 22       | 1958 | 589-811              | $\leq$ 2          | Stably oxidized at 811 K in quiescent air.  |
| 4         | 58       | 1961 | 673-1773             | $\pm$ 2.5         | Lightly etched and flashed in vacuum at 2073 K for 10 min; measured in vacuum ( $<5 \times 10^{-6}$ mm Hg); data extracted from smooth curve.   |
| 5         | 58       | 1961 | 773-1493             | $\pm$ 2.5         | Shot-blasted and pickled in hydrochloric acid to remove iron; measured in vacuum ( $<5 \times 10^{-6}$ mm Hg); data extracted from smooth curve.  |
| 6         | 70       | 1960 | 2300-2900            |                   | 0.18 Fe, 0.073 Si, 0.04 C, 0.036 Mn, 0.005 O <sub>2</sub> , 0.01 others, Mo balance; cast under inert gas; hot rolled; successively polished with No. 1-, 0-, 00-, 000-, and 0000- abrasive papers; measured in argon.                                |
| 7         | 71       | 1962 | 1540-2180            | $\pm$ 10          | Measured in vacuum ( $<10^{-5}$ mm Hg).   |
| 8         | 72       | 1963 | 1506-2825            |                   | 0.07 - 0.09 Fe, 0.04 - 0.06 Nb, 0.001 - 0.003 Mn, 0.001 - 0.003 Si, 0.0004 - 0.0006 Cu, 0.0001 - 0.0005 Mg, Mo balance; thin walled tube; polished using felt with a GOI paste; annealed; measured in vacuum.   |
| 9         | 73       | 1964 | 1200-1700            | < 2.3             | 99.96 Mo, 0.004 SiO <sub>2</sub> , 0.004 CaO and MgO, 0.026 sesquioxides; prepared by rubbing with abrasive paper; surface roughness 0.063 - 0.050 $\mu$ RMS; measured in vacuum ( $10^{-3}$ to $10^{-4}$ mm Hg); [Author's designation: Specimen 1]. |
| 10        | 73       | 1964 | 1200-1700            | < 2.3             | Different sample, same as curve 9 specimen and conditions; [Author's designation: Specimen 2].  |
| 11        | 73       | 1964 | 1200-1700            | < 2.3             | Different sample, same as curve 9 specimen; same conditions except surface roughness 1.25 - 1.00 $\mu$ RMS; [Author's designation: Specimen 3].   |
| 12        | 54       | 1962 | 1070-1990            | $\pm$ 4           | Degreased with acetone, cleaned with a rubber eraser, wiped with acetone; measured in vacuum ( $10^{-4}$ to $10^{-6}$ mm Hg); same data reported for both samples; [Author's designation: Sample No. 1 and Sample No. 2].                             |
| 13        | 54       | 1962 | 1185-1905            | $\pm$ 4           | Degreased with acetone, cleaned with a rubber eraser, wiped with acetone; aged for 1 hr at 1773 K; measured in vacuum ( $10^{-4}$ to $10^{-6}$ mm Hg); [Author's designation: Sample 2].  |
| 14        | 54       | 1962 | 1100-1800            | $\pm$ 4           | Polished using rouge in wax on a buffering wheel; measured in vacuum ( $10^{-4}$ to $10^{-6}$ mm Hg); [Author's designation: Sample No. 3].   |
| 15        | 54       | 1962 | 800-1300             | $\pm$ 4           | Polished using fine aluminum oxide powder on a circular rotatable drum with a rotating lap; measured in vacuum ( $10^{-4}$ to $10^{-5}$ mm Hg); cycle 1; [Author's designation: Sample No. 5].  |
| 16        | 54       | 1962 | 800-1300             | $\pm$ 4           | Above specimen and conditions; cycle 2.   |
| 17        | 54       | 1962 | 1400-1800            | $\pm$ 4           | Different sample, same as curve 15 specimen and conditions; cycle 1; [Author's designation: Sample No. 6].  |
| 18        | 54       | 1962 | 1100-1300            | $\pm$ 4           | Above specimen and conditions; cycle 2.   |

SPECIFICATION TABLE NO. 132 (continued)

29

| Curve No. | Ref. No. | Year | Temperature Range, K | Reported Error, % | Composition (weight percent), Specifications and Remarks  |
|-----------|----------|------|----------------------|-------------------|---|
| 19        | 54       | 1962 | 1800                 | $\pm$ 4           | Above specimen and conditions; cycle 3.   |
| 20        | 54       | 1962 | 1300-1500            | $\pm$ 4           | Above specimen and conditions; cycle 4.   |
| 21        | 54       | 1962 | 1000-2000            | $\pm$ 4           | Above specimen and conditions; cycle 5.   |
| 22        | 12       | 1962 | 385.6-1075.1         | $\pm$ 2.7         | Grit blasted with aluminum oxide No. 90 (PMC-3043A); measured in vacuum ( $<2.9 \times 10^{-6}$ mm Hg); Run No. 1.            |
| 23        | 12       | 1962 | 1061.1-1251.5        | $\pm$ 2.7         | Above specimen and conditions; Run No. 2A.  |
| 24        | 12       | 1962 | 1255.1-1235.9        | $\pm$ 2.7         | Above specimen and conditions; Run No. 2B.  |
| 25        | 12       | 1962 | 491.2-1385.2         | $\pm$ 2.7         | Vapor-blasted with Techline Liquabrasive, PMC-3067, grit No. 325; measured in vacuum ( $<5 \times 10^{-6}$ mm Hg); Run No. 1. |
| 26        | 12       | 1962 | 545.2-1375.7         | $\pm$ 2.7         | Above specimen and conditions; Run No. 2.   |
| 27        | 12       | 1962 | 412-1373             | $\pm$ 2.7         | Above specimen and conditions; Run No. 3.   |
| 28        | 12       | 1962 | 410-1244             | $\pm$ 2.7         | Above specimen and conditions; Run No. 4A.  |
| 29        | 12       | 1962 | 1378-1273            | $\pm$ 2.7         | Above specimen and conditions; Run No. 4B.  |
| 30        | 12       | 1962 | 429.2-1401.2         | $\pm$ 2.7         | Chemically cleaned; measured in vacuum ( $<5 \times 10^{-6}$ mm Hg); Run No. 1.   |
| 31        | 12       | 1962 | 449.7-1405.2         | $\pm$ 2.7         | Above specimen and conditions; Run No. 2.   |
| 32        | 12       | 1962 | 407.2-1374.2         | $\pm$ 2.7         | Above specimen and conditions; Run No. 3A.  |
| 33        | 12       | 1962 | 1002.4-1169.2        | $\pm$ 2.7         | Above specimen and conditions; Run No. 3B.  |
| 34        | 12       | 1962 | 1054-1538            | $\pm$ 2.3         | As received; measured in vacuum ( $<2 \times 10^{-6}$ mm Hg); Run No. 1A.   |
| 35        | 12       | 1962 | 1539-1100            | $\pm$ 2.3         | Above specimen and conditions; Run No. 1B.  |
| 36        | 12       | 1962 | 1242-1540            | $\pm$ 2.3         | Above specimen and conditions; Run No. 2.   |
| 37        | 12       | 1962 | 1045-1539            | $\pm$ 2.7         | As received; measured in vacuum ( $<2 \times 10^{-6}$ mm Hg); Run No. 1A.   |
| 38        | 12       | 1962 | 1535-1097            | $\pm$ 2.7         | Above specimen and conditions; Run No. 1B.  |
| 39        | 12       | 1962 | 1239-1541            | $\pm$ 2.7         | Above specimen and conditions; Run No. 2.   |
| 40        | 12       | 1962 | 1368-998             | $\pm$ 2.7         | Grit blasted with aluminum oxide No. 90 (PMC-3043A); measured in vacuum ( $<5.1 \times 10^{-6}$ mm Hg); Run No. 1.            |

## DATA TABLE NO. 132 HEMISPHERICAL TOTAL EMITTANCE OF MOLYBDENUM

{Temperature, T, K; Emittance, ε}

| T              | ε     | T                      | ε               | T                      | ε               | T                       | ε               | T                       | ε                | T               | ε                | T                       | ε                |
|----------------|-------|------------------------|-----------------|------------------------|-----------------|-------------------------|-----------------|-------------------------|------------------|-----------------|------------------|-------------------------|------------------|
| <u>CURVE 1</u> |       | <u>CURVE 6 (cont.)</u> |                 | <u>CURVE 8 (cont.)</u> |                 | <u>CURVE 10 (cont.)</u> |                 | <u>CURVE 13 (cont.)</u> |                  | <u>CURVE 18</u> |                  | <u>CURVE 22 (cont.)</u> |                  |
| 468            | 0.07  | 2440                   | 0.279           | 2175                   | 0.2325          | 1650                    | 0.186           | 1290                    | 0.230            | 1100            | 0.115            | 778.2                   | 0.303            |
| 668            | 0.09  | 2500                   | 0.278           | 2212                   | 0.2337          | 1700                    | 0.192           | 1305                    | 0.230            | 1200            | 0.135*           | 808.5                   | 0.310            |
| 873            | 0.12  | 2565                   | 0.282           | 2225                   | 0.2375          |                         |                 | 1370                    | 0.237            | 1300            | 0.157*           | 845.3                   | 0.312            |
| 1093           | 0.13  | 2600                   | 0.282           | 2218                   | 0.2400          |                         | <u>CURVE 11</u> | 1390                    | 0.240            | 1300            | 0.185            | 870.6                   | 0.312            |
|                |       | 2630                   | 0.281           | 2237                   | 0.2450          | 1200                    | 0.143           | 1500                    | 0.257            | 1300            | 0.200            | 904.0                   | 0.320            |
| <u>CURVE 2</u> |       | 2655                   | 0.281           | 2275                   | 0.2325          | 1250                    | 0.150           | 1600                    | 0.277            | 1300            | 0.240            | 952.2                   | 0.330            |
| 1544           | 0.280 | 2695                   | 0.282           | 2300                   | 0.2400          | 1300                    | 0.157           | 1705                    | 0.255            |                 |                  | 975.7                   | 0.329            |
| 1686           | 0.300 | 2760                   | 0.285           | 2356                   | 0.2475          | 1350                    | 0.164           | 1810                    | 0.300            |                 | <u>CURVE 19</u>  | 1001.7                  | 0.334            |
| 1822           | 0.315 | 2800                   | 0.285           | 2400                   | 0.2475          | 1400                    | 0.171           | 1905                    | 0.310            |                 |                  | 1030.2                  | 0.339            |
| 1967           | 0.320 | 2825                   | 0.285           | 2406                   | 0.2600          | 1450                    | 0.178           |                         |                  | 1800            | 0.300            | 1071.5                  | 0.337            |
| 2033           | 0.325 | 2900                   | 0.285           | 2412                   | 0.2575          | 1500                    | 0.185           |                         | <u>CURVE 14*</u> | 1800            | 0.275            | 1075.1                  | 0.330            |
| 2103           | 0.325 |                        |                 | 2518                   | 0.2575          | 1550                    | 0.192           | 1100                    | 0.195            | 1800            | 0.273            |                         |                  |
| 2172           | 0.325 |                        | <u>CURVE 7*</u> | 2506                   | 0.2687          | 1600                    | 0.198           | 1195                    | 0.207            |                 |                  |                         | <u>CURVE 23</u>  |
|                |       |                        |                 | 2575                   | 0.2675          | 1650                    | 0.205           | 1400                    | 0.235            |                 | <u>CURVE 20*</u> | 1061.1                  | 0.323            |
| <u>CURVE 3</u> |       | 1540                   | 0.275           | 2612                   | 0.2700          | 1700                    | 0.211           | 1600                    | 0.255            |                 |                  | 1092.2                  | 0.329            |
| 589            | 0.785 | 1690                   | 0.300           | 2662                   | 0.2712          |                         |                 | 1800                    | 0.280            | 1300            | 0.215            | 1123.6                  | 0.326            |
| 644            | 0.830 | 1830                   | 0.310           | 2650                   | 0.2662          |                         | <u>CURVE 12</u> | 1070                    | 0.190            |                 | <u>CURVE 15*</u> | 1134.1                  | 0.335            |
| 700            | 0.825 | 1970                   | 0.320           | 2700                   | 0.2750          |                         |                 | 1100                    | 0.200            | 800             | 0.085            | 1156.4                  | 0.344            |
| 753            | 0.810 | 2040                   | 0.325           | 2750                   | 0.2750          | 1070                    | 0.190           | 900                     | 0.090            |                 | <u>CURVE 21*</u> | 1210.2                  | 0.341            |
| 811            | 0.805 | 2110                   | 0.326           | 2825                   | 0.2812          | 1100                    | 0.200           | 1000                    | 0.100            | 1000            | 0.185            | 1234.8                  | 0.346            |
|                |       | 2180                   | 0.326           |                        |                 | 1200                    | 0.210           | 1100                    | 0.113            | 1100            | 0.200            | 1241.6                  | 0.339            |
| <u>CURVE 4</u> |       |                        | <u>CURVE 8</u>  |                        | <u>CURVE 9</u>  | 1205                    | 0.210           | 1200                    | 0.132            | 1200            | 0.215            | 1247.8                  | 0.332            |
| 673            | 0.065 | 1506                   | 0.1580          | 1200                   | 0.117           | 1300                    | 0.220           | 1300                    | 0.157            | 1300            | 0.230            | 1251.5                  | 0.328            |
| 873            | 0.115 | 1588                   | 0.1650          | 1250                   | 0.123           | 1300                    | 0.225           | 1310                    | 0.170            | 1400            | 0.247            |                         | <u>CURVE 24*</u> |
| 1073           | 0.175 | 1638                   | 0.1850          | 1300                   | 0.130           | 1305                    | 0.223           | 1310                    | 0.177            | 1600            | 0.280            | 1255.1                  | 0.324            |
| 1273           | 0.240 | 1738                   | 0.1925          | 1350                   | 0.136           | 1380                    | 0.230           | 1310                    | 0.185            | 1700            | 0.295            | 1235.9                  | 0.320            |
| 1473           | 0.315 | 1750                   | 0.1825          | 1400                   | 0.143           | 1385                    | 0.233           | 1310                    | 0.210            | 1800            | 0.305            |                         | <u>CURVE 25</u>  |
| 1673           | 0.390 | 1775                   | 0.1875          | 1450                   | 0.149           | 1405                    | 0.240           | 1410                    | 0.237            | 1300            | 0.217            | 1900                    | 0.310            |
| 1773           | 0.430 | 1825                   | 0.1975          | 1500                   | 0.155           | 1410                    | 0.237           | 1495                    | 0.245            | 1300            | 0.222            | 2000                    | 0.312            |
|                |       | 1856                   | 0.1825          | 1550                   | 0.161           | 1495                    | 0.245           |                         |                  |                 |                  | 491.2                   | 0.082            |
| <u>CURVE 5</u> |       | 1906                   | 0.1987          | 1600                   | 0.167           | 1500                    | 0.245           |                         |                  |                 |                  | 625.2                   | 0.099            |
|                |       | 1912                   | 0.1912          | 1650                   | 0.173           | 1500                    | 0.245*          |                         | <u>CURVE 16</u>  |                 |                  | 762.2                   | 0.109            |
| 773            | 0.215 | 1930                   | 0.2075          | 1700                   | 0.178           | 1600                    | 0.260           | 800                     | 0.155            | 385.6           | 0.272            |                         |                  |
| 873            | 0.245 | 1975                   | 0.2200          |                        |                 | 1600                    | 0.263*          | 900                     | 0.165            | 446.7           | 0.276            | 900.2                   | 0.133            |
| 1073           | 0.300 | 2006                   | 0.2125          |                        | <u>CURVE 10</u> | 1600                    | 0.265           | 1000                    | 0.180            | 485.6           | 0.268            | 1018.2                  | 0.141            |
| 1273           | 0.355 | 2025                   | 0.2250          | 1200                   | 0.124           | 1705                    | 0.275           | 1100                    | 0.192            | 514.6           | 0.272            | 1161.2                  | 0.163            |
| 1473           | 0.410 | 2031                   | 0.2200          | 1250                   | 0.136           | 1705                    | 0.275*          | 1200                    | 0.205            | 554.2           | 0.277            | 1270.2                  | 0.173            |
| 1493           | 0.415 | 2062                   | 0.2150          | 1300                   | 0.142           | 1805                    | 0.285           | 1300                    | 0.222*           | 587.8           | 0.280            | 1385.2                  | 0.180            |
|                |       | 2081                   | 0.2225          | 1350                   | 0.149           | 1900                    | 0.245           |                         |                  | 621.3           | 0.277            |                         | <u>CURVE 26*</u> |
| <u>CURVE 6</u> |       | 2112                   | 0.2225          | 1400                   | 0.156           | 1990                    | 0.305           |                         |                  | 655.0           | 0.278            |                         |                  |
|                |       | 2137                   | 0.2200          | 1450                   | 0.162           |                         |                 |                         | <u>CURVE 17*</u> | 686.9           | 0.284            | 545.2                   | 0.055            |
| 2300           | 0.276 | 2137                   | 0.2275          | 1500                   | 0.168           |                         | <u>CURVE 13</u> | 1400                    | 0.160            | 716.6           | 0.295            | 685.7                   | 0.065            |
| 2370           | 0.274 | 2162                   | 0.2225          | 1550                   | 0.174           |                         |                 | 1600                    | 0.190            | 750.4           | 0.298            | 813.2                   | 0.082            |
| 2400           | 0.276 |                        |                 | 1600                   | 0.180           | 1185                    | 0.217           | 1800                    | 0.217            | 751.8           | 0.297*           | 936.2                   | 0.101            |

\* Not shown on plot

DATA TABLE NO. 132 (continued)

| T                       | ε     | T                | ε     | T                       | ε     | T               | ε     |
|-------------------------|-------|------------------|-------|-------------------------|-------|-----------------|-------|
| <u>CURVE 26 (cont.)</u> |       | <u>CURVE 31*</u> |       | <u>CURVE 35 (cont.)</u> |       | <u>CURVE 40</u> |       |
| 545.2                   | 0.055 | 449.7            | 0.043 | 1135                    | 0.109 | 1368            | 0.314 |
| 685.7                   | 0.065 | 594.2            | 0.054 | 1100                    | 0.104 | 1308            | 0.302 |
| 813.2                   | 0.082 | 696.2            | 0.062 |                         |       | 1266            | 0.290 |
| 936.2                   | 0.101 | 784.2            | 0.069 | <u>CURVE 36*</u>        |       | 1233            | 0.281 |
| 1084.2                  | 0.126 | 913.7            | 0.081 | 1242                    | 0.122 | 1204            | 0.280 |
| 1191.7                  | 0.143 | 1052.9           | 0.098 | 1290                    | 0.128 | 1180            | 0.269 |
| 1308.7                  | 0.163 | 1177.2           | 0.112 | 1337                    | 0.134 | 1149            | 0.264 |
| 1375.7                  | 0.173 | 1318.2           | 0.135 | 1387                    | 0.143 | 1125            | 0.260 |
|                         |       | 1405.2           | 0.146 | 1431                    | 0.149 | 1093            | 0.253 |
| <u>CURVE 27</u>         |       | <u>CURVE 32*</u> |       | 1481                    | 0.156 | 1063            | 0.248 |
| 412                     | 0.043 | 407.2            | 0.034 | 1540                    | 0.165 | 1034            | 0.242 |
| 545                     | 0.052 | 502.8            | 0.041 |                         |       | 1004            | 0.235 |
| 675                     | 0.068 | 590.2            | 0.055 | <u>CURVE 37*</u>        |       | 998             | 0.236 |
| 797                     | 0.081 | 767.0            | 0.066 | 1045                    | 0.122 |                 |       |
| 909                     | 0.096 | 889.2            | 0.077 | 1083                    | 0.125 |                 |       |
| 1007                    | 0.111 | 1159.2           | 0.113 | 1140                    | 0.131 |                 |       |
| 1131                    | 0.129 | 1283.2           | 0.130 | 1201                    | 0.135 |                 |       |
| 1255                    | 0.148 | 1374.2           | 0.142 | 1258                    | 0.139 |                 |       |
| 1373                    | 0.172 |                  |       | 1311                    | 0.143 |                 |       |
| <u>CURVE 28*</u>        |       | <u>CURVE 33</u>  |       | 1366                    | 0.150 |                 |       |
| 410                     | 0.038 | 1002.4           | 0.130 | 1475                    | 0.158 |                 |       |
| 553                     | 0.050 | 1169.2           | 0.112 | 1539                    | 0.165 |                 |       |
| 646                     | 0.061 |                  |       | <u>CURVE 38*</u>        |       |                 |       |
| 768                     | 0.073 | <u>CURVE 34</u>  |       | 1535                    | 0.167 |                 |       |
| 892                     | 0.088 | 1054             | 0.118 | 1480                    | 0.156 |                 |       |
| 990                     | 0.100 | 1089             | 0.123 | 1429                    | 0.150 |                 |       |
| 1114                    | 0.121 | 1145             | 0.128 | 1385                    | 0.143 |                 |       |
| 1244                    | 0.139 | 1209             | 0.132 | 1333                    | 0.136 |                 |       |
|                         |       | 1263             | 0.136 | 1264                    | 0.131 |                 |       |
| <u>CURVE 29*</u>        |       | 1315             | 0.142 | 1237                    | 0.124 |                 |       |
| 1378                    | 0.163 | 1374             | 0.147 | 1184                    | 0.117 |                 |       |
| 1273                    | 0.144 | 1426             | 0.158 | 1131                    | 0.110 |                 |       |
|                         |       | 1538             | 0.165 | 1097                    | 0.105 |                 |       |
| <u>CURVE 30</u>         |       | <u>CURVE 35*</u> |       | <u>CURVE 39*</u>        |       |                 |       |
| 429.2                   | 0.056 | 1539             | 0.165 | 1239                    | 0.124 |                 |       |
| 520.2                   | 0.063 | 1481             | 0.156 | 1286                    | 0.130 |                 |       |
| 648.2                   | 0.073 | 1431             | 0.149 | 1333                    | 0.136 |                 |       |
| 763.2                   | 0.082 | 1387             | 0.143 | 1385                    | 0.144 |                 |       |
| 919.2                   | 0.097 | 1335             | 0.135 | 1429                    | 0.150 |                 |       |
| 1054.2                  | 0.112 | 1290             | 0.128 | 1480                    | 0.156 |                 |       |
| 1198.2                  | 0.128 | 1243             | 0.122 | 1541                    | 0.164 |                 |       |
| 1307.7                  | 0.139 | 1188             | 0.115 |                         |       |                 |       |

\* Not shown on plot

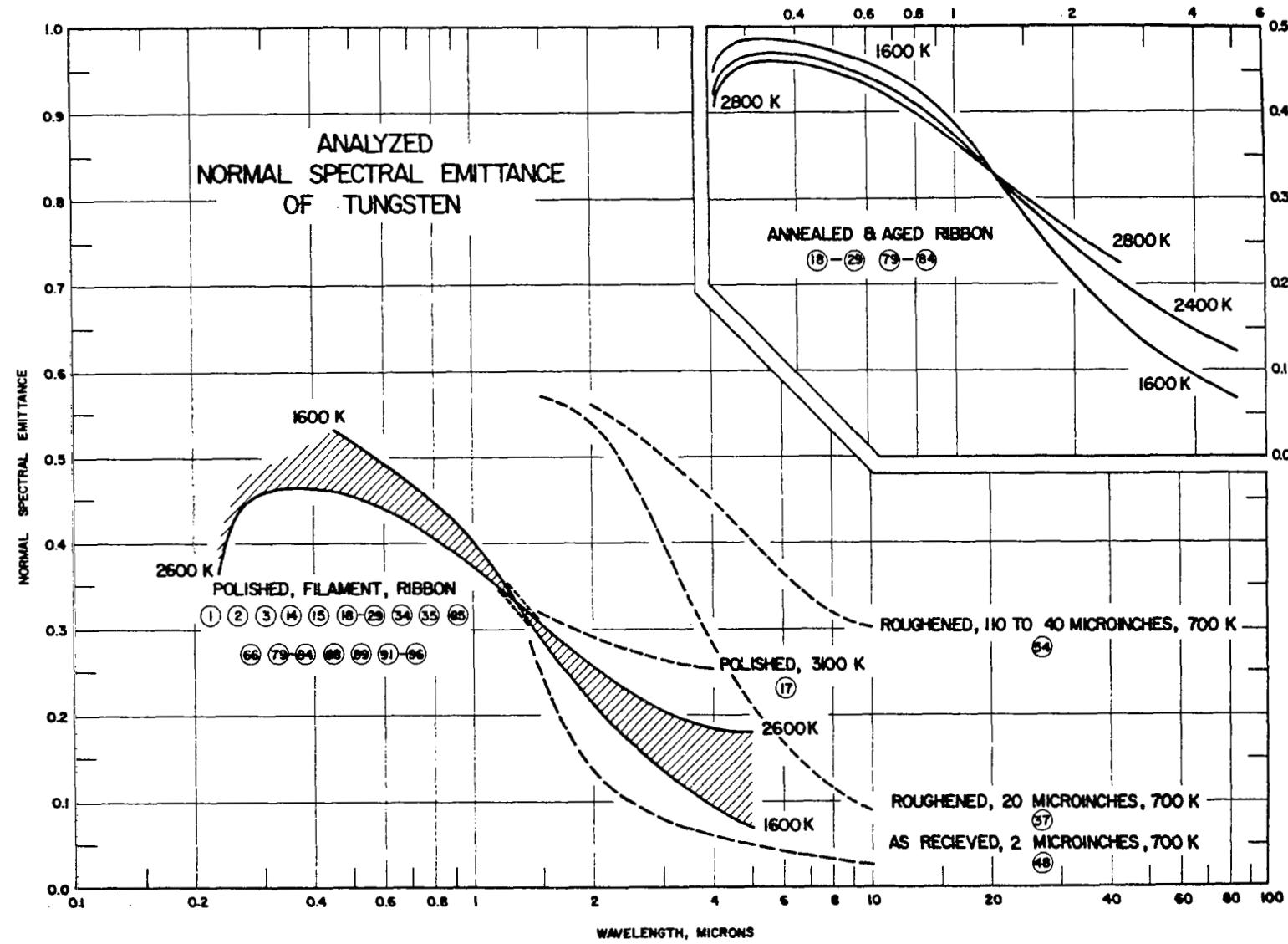
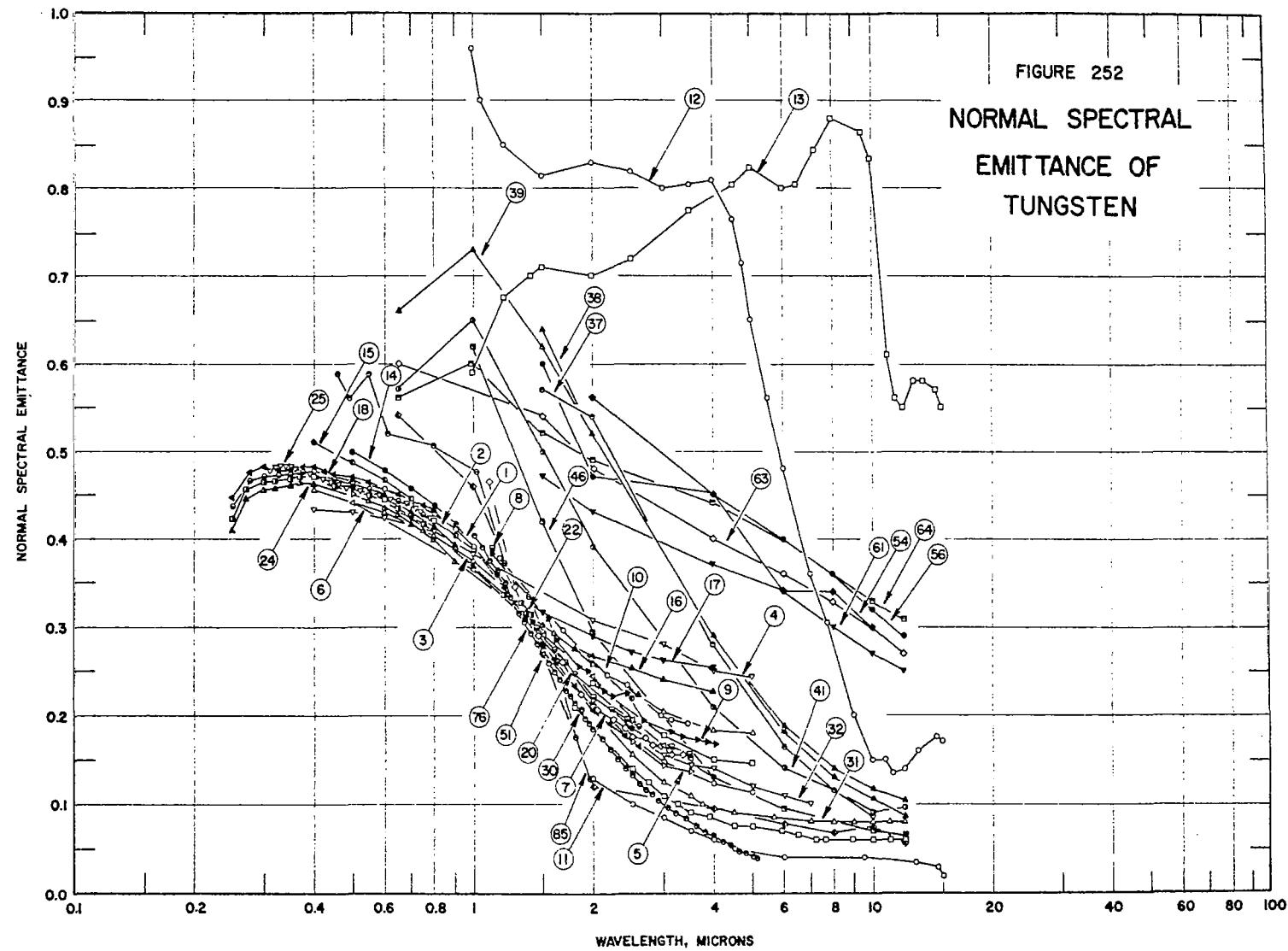


FIGURE 252

NORMAL SPECTRAL  
EMITTANCE OF  
TUNGSTEN

## SPECIFICATION TABLE NO. 252 NORMAL SPECTRAL EMITTANCE OF TUNGSTEN

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| Curve No. | Ref. No. | Year | Temperature K | Wavelength Range, $\mu$ | Geometry $\theta'$ | Reported Error, % | Composition (weight percent), Specifications and Remarks   |
|-----------|----------|------|---------------|-------------------------|--------------------|-------------------|--|
| 1         | 112      | 1963 | 1605          | 0.4-5.0                 | $\sim 0^\circ$     |                   | Polished single crystal tungsten; measured in argon (1140 mm Hg) along 002 crystal plane; data extracted from smooth curve.  |
| 2         | 112      | 1963 | 2140          | 0.4-5.0                 | $\sim 0^\circ$     |                   | Above specimen and conditions.   |
| 3         | 112      | 1963 | 2639          | 0.4-5.0                 | $\sim 0^\circ$     |                   | Above specimen and conditions.   |
| 4         | 112      | 1963 | 2650          | 0.4-5.0                 | $\sim 0^\circ$     |                   | Above specimen and conditions.   |
| 5         | 113      | 1961 | 1830          | 0.5-3.5                 | $\sim 0^\circ$     |                   | Measured in argon (760 mm Hg); data extracted from smooth curve.   |
| 6         | 113      | 1961 | 2040          | 0.5-3.5                 | $\sim 0^\circ$     |                   | Above specimen and conditions.   |
| 7         | 113      | 1961 | 1316          | 1.10-3.47               | $\sim 0^\circ$     |                   | Trace of surface oxidation observed; measured in vacuum.   |
| 8         | 113      | 1961 | 1340          | 1.12-3.48               | $\sim 0^\circ$     |                   | Above specimen and conditions.   |
| 9         | 113      | 1961 | 1382          | 1.13-4.04               | $\sim 0^\circ$     |                   | Above specimen and conditions except measured in argon (760 mm Hg).  |
| 10        | 113      | 1961 | 1429          | 1.16-3.48               | $\sim 0^\circ$     |                   | Above specimen and conditions.   |
| 11        | 86       | 1961 | 523           | 2.00-15.00              | $\sim 0^\circ$     | $\pm 5$           | As received; data extracted from smooth curve.   |
| 12        | 86       | 1961 | 773           | 1.00-15.00              | $\sim 0^\circ$     |                   | Different sample, same as curve 11 specimen and conditions.  |
| 13        | 86       | 1961 | 1023          | 1.00-15.00              | $\sim 0^\circ$     | $\pm 5$           | Different sample, same as curve 11 specimen and conditions.  |
| 14        | 95       | 1963 | 1600          | 0.50-4.00               | $\sim 0^\circ$     |                   | 99.9 W from Carbide Specialty Co.; polished with carbide paper of 240, 400, and 600 grit, respectively, and then with silk cloth and felt cloth; washed in acetone, then alcohol, and dried with dry nitrogen; data extracted from smooth curve. |
| 15        | 95       | 1963 | 2000          | 0.40-4.00               | $\sim 0^\circ$     |                   | Above specimen and conditions.   |
| 16        | 95       | 1963 | 2800          | 0.40-4.00               | $\sim 0^\circ$     |                   | Above specimen and conditions.   |
| 17        | 95       | 1963 | 3100          | 0.40-4.00               | $\sim 0^\circ$     |                   | Above specimen and conditions.   |
| 18        | 114      | 1954 | 1600          | 0.25-2.60               | $\sim 0^\circ$     | 0.1               | 0.014-0.015 Fe, 0.004-0.008 Si, 0.001-0.003 Mn, 0.0003-0.0006 Mg, W balance; heated at 2400 K, treated in hydrogen, annealed at 2400 K for 100 hrs; measured in vacuum ( $5 \times 10^{-6}$ mm Hg); data extracted from smooth curve.            |
| 19        | 114      | 1954 | 1800          | 0.25-2.60               | $\sim 0^\circ$     | 0.1               | Above specimen and conditions.   |
| 20        | 114      | 1954 | 2000          | 0.25-2.60               | $\sim 0^\circ$     | 0.1               | Above specimen and conditions.   |
| 21        | 114      | 1954 | 2200          | 0.25-2.60               | $\sim 0^\circ$     | 0.1               | Above specimen and conditions.   |
| 22        | 114      | 1954 | 2400          | 0.25-2.60               | $\sim 0^\circ$     | 0.1               | Above specimen and conditions.   |
| 23        | 114      | 1954 | 2600          | 0.25-2.60               | $\sim 0^\circ$     | 0.1               | Above specimen and conditions except measured in argon (500 mm Hg).  |
| 24        | 114      | 1954 | 2800          | 0.25-2.60               | $\sim 0^\circ$     | 0.1               | Above specimen and conditions.   |
| 25        | 115      | 1959 | 1600          | 0.310-0.800             | $\sim 0^\circ$     |                   | Better than 99.99 percent pure; heated at 2750 K for 1/2 hr in vacuum, then annealed at 2500 K for 30 hrs, at 2800 K for 1/2 hr, and at 2500 K for 20 hrs; measured in vacuum ( $3 \times 10^{-9}$ to $9.5 \times 10^{-8}$ mm Hg).               |

SPECIFICATION TABLE NO. 252 (continued)

| Curve No. | Ref. No. | Year | Temperature K | Wavelength Range. $\mu$ | Geometry $\theta^{\circ}$ | Reported Error, % | Composition (weight percent), Specifications and Remarks  |
|-----------|----------|------|---------------|-------------------------|---------------------------|-------------------|---|
| 26        | 115      | 1959 | 1800          | 0.310-0.800             | $\sim 0^{\circ}$          |                   | Above specimen and conditions.  |
| 27        | 115      | 1959 | 2000          | 0.310-0.800             | $\sim 0^{\circ}$          |                   | Above specimen and conditions.  |
| 28        | 115      | 1959 | 2200          | 0.310-0.800             | $\sim 0^{\circ}$          |                   | Above specimen and conditions.  |
| 29        | 115      | 1959 | 2400          | 0.310-0.800             | $\sim 0^{\circ}$          |                   | Above specimen and conditions.  |
| 30        | 12       | 1962 | 1200          | 0.50-12.00              | $\sim 0^{\circ}$          | $\pm 3$           | Measured in vacuum ( $< 10^{-7}$ mm Hg).  |
| 31        | 12       | 1962 | 1428          | 0.50-12.00              | $\sim 0^{\circ}$          | $\pm 3$           | Above specimen and conditions.  |
| 32        | 12       | 1962 | 1972          | 0.45-7.00               | $\sim 0^{\circ}$          | $\pm 3$           | Above specimen and conditions.  |
| 33        | 241      | 1963 | 1660          | 1.10-1.70               | 0                         | <1                | Single crystal; oriented so that surface of interest coincided with closed packed plane; optically polished; heated at several hundred degrees above temperature of interest in 90 Ar + 10 H atm; computed from optical constants.                  |
| 34        | 241      | 1963 | 1790          | 0.9-1.7                 | $0^{\circ}$               | <1                | Above specimen and conditions.  |
| 35        | 241      | 1963 | 1950          | 0.90-1.70               | $0^{\circ}$               | <1                | Above specimen and conditions.  |
| 36        | 241      | 1963 | 2050          | 0.90-1.70               | $0^{\circ}$               | <1                | Above specimen and conditions.  |
| 37        | 227      | 1964 | 693           | 1.5-10                  | $\sim 0^{\circ}$          |                   | Impurities <40 ppm; grit blasted; surface roughness 17 microinches rms, 21 microinches rms after emittance test; preheated in vacuum at 1000 K for 0.5 hr; measured in vacuum ( $8 \times 10^{-6}$ mm Hg); [Author's designation: Sample 2].        |
| 38        | 227      | 1964 | 860           | 1.5-12                  | $\sim 0^{\circ}$          |                   | Above specimen and conditions.  |
| 39        | 227      | 1964 | 1033          | 0.65-12                 | $\sim 0^{\circ}$          |                   | Above specimen and conditions.  |
| 40        | 227      | 1964 | 1200          | 0.65-12                 | $\sim 0^{\circ}$          |                   | Above specimen and conditions.  |
| 41        | 227      | 1964 | 1373          | 0.65-12                 | $\sim 0^{\circ}$          |                   | Above specimen and conditions.  |
| 42        | 227      | 1964 | 1603          | 0.65-4                  | $\sim 0^{\circ}$          |                   | Above specimen and conditions.  |
| 43        | 227      | 1964 | 698           | 1.5-10                  | $\sim 0^{\circ}$          |                   | Above specimen and conditions except second temperature cycle.  |
| 44        | 227      | 1964 | 860           | 1.5-10                  | $\sim 0^{\circ}$          |                   | Above specimen and conditions.  |
| 45        | 227      | 1964 | 1029          | 1-12                    | $\sim 0^{\circ}$          |                   | Above specimen and conditions.  |
| 46        | 227      | 1964 | 1196          | 1-12                    | $\sim 0^{\circ}$          |                   | Above specimen and conditions.  |
| 47        | 227      | 1964 | 1378          | 1.5-4                   | $\sim 0^{\circ}$          |                   | Above specimen and conditions.  |
| 48        | 227      | 1964 | 702           | 1.5-10                  | $\sim 0^{\circ}$          |                   | Impurities <40 ppm; as received; surface roughness 1.5 microinches rms before emittance test, 2.4 microinches rms after emittance; preheated in vacuum for 2 hrs; measured in vacuum ( $7 \times 10^{-6}$ mm Hg); [Author's designation: Sample 1]. |
| 49        | 227      | 1964 | 870           | 1.5-10                  | $\sim 0^{\circ}$          |                   | Above specimen and conditions.  |
| 50        | 227      | 1964 | 1039          | 1.5-12                  | $\sim 0^{\circ}$          |                   | Above specimen and conditions.  |

SPECIFICATION TABLE NO. 252 (continued)

| Curve No. | Ref. No. | Year | Temperature K | Wavelength Range, $\mu$ | Geometry $\theta^i$ | Reported Error, % | Composition (weight percent), Specifications and Remarks   |
|-----------|----------|------|---------------|-------------------------|---------------------|-------------------|--|
| 51        | 227      | 1964 | 1208          | 0.65-12                 | $\sim 0^\circ$      |                   | Above specimen and conditions.   |
| 52        | 227      | 1964 | 1378          | 0.65-4                  | $\sim 0^\circ$      |                   | Above specimen and conditions.   |
| 53        | 227      | 1964 | 1603          | 0.65-4                  | $\sim 0^\circ$      |                   | Above specimen and conditions.   |
| 54        | 227      | 1962 | 692           | 2-10                    | $\sim 0^\circ$      |                   | Impurities <40 ppm; grit blasted; surface roughness 110 microinches rms before emittance test, 38 microinches after emittance test; preheated in vacuum at 1000 K for 0.5 hr; measured in vacuum ( $5 \times 10^{-5}$ mm Hg); $\omega^i = 3.4 \times 10^{-4}$ sr.; [Author's designation: Sample 3]. |
| 55        | 227      | 1964 | 863           | 1.5-12                  | $\sim 0^\circ$      |                   | Above specimen and conditions.   |
| 56        | 227      | 1964 | 1040          | 1.5-12                  | $\sim 0^\circ$      |                   | Above specimen and conditions.   |
| 57        | 227      | 1964 | 1214          | 0.65-12                 | $\sim 0^\circ$      |                   | Above specimen and conditions.   |
| 58        | 227      | 1964 | 1383          | 0.65-12                 | $\sim 0^\circ$      |                   | Above specimen and conditions.   |
| 59        | 227      | 1964 | 699           | 1.5-10                  | $\sim 0^\circ$      |                   | Above specimen and conditions.   |
| 60        | 227      | 1964 | 529           | 1.5-10                  | $\sim 0^\circ$      |                   | Above specimen and conditions.   |
| 61        | 227      | 1964 | 700           | 1.5-12                  | $\sim 0^\circ$      |                   | Above specimen and conditions.   |
| 62        | 227      | 1964 | 858           | 1.5-12                  | $\sim 0^\circ$      |                   | Above specimen and conditions.   |
| 63        | 227      | 1964 | 1198          | 0.65-12                 | $\sim 0^\circ$      |                   | Above specimen and conditions.   |
| 64        | 227      | 1964 | 1358          | 0.65-12                 | $\sim 0^\circ$      |                   | Above specimen and conditions.   |
| 65        | 76       | 1962 | 1600          | 0.50-4.00               | $\sim 0^\circ$      |                   | Prepared from micronized powder; hot pressed at >2273 K; sintered, polished, etched, then degassed by heating to ~973 K; measured in argon; data extracted from smooth curve.  |
| 66        | 76       | 1962 | 2000          | 0.40-4.00               | $\sim 0^\circ$      |                   | Above specimen and conditions.   |
| 67        | 76       | 1962 | 2800          | 0.40-4.00               | $\sim 0^\circ$      |                   | Above specimen and conditions.   |
| 68        | 76       | 1962 | 3100          | 0.40-4.00               | $\sim 0^\circ$      |                   | Above specimen and conditions.   |
| 69        | 239      | 1959 | 1429          | 1.157-3.486             | $\sim 0^\circ$      | 5                 | Highly polished; measured in argon.  |
| 70        | 239      | 1959 | 1382          | 1.127-4.038             | $\sim 0^\circ$      | 5                 | Different sample, same as above specimen and conditions.   |
| 71        | 239      | 1959 | 1340          | 1.120-3.485             | $\sim 0^\circ$      | 5                 | Different sample, same as above specimen and conditions.   |
| 72        | 239      | 1959 | 1316          | 1.096-3.459             | $\sim 0^\circ$      | 5                 | Different sample, same as above specimen and conditions.   |
| 73        | 237      | 1965 | 1800          | 0.467-0.698             | $\sim 0^\circ$      |                   | Chemically pure; measured in vacuum; authors assumed $\epsilon = 1 - \rho$ and computed $\rho$ from optical constants.   |
| 74        | 237      | 1965 | 2150          | 0.467-0.698             | $\sim 0^\circ$      |                   | Above specimen and conditions.   |
| 75        | 237      | 1965 | 2520          | 0.467-0.698             | $\sim 0^\circ$      |                   | Above specimen and conditions.   |

SPECIFICATION TABLE NO. 252 (continued)

| Curve No. | Ref. No. | Year | Temperature K | Wavelength Range, $\mu$ | Geometry $\theta'$ | Reported Error, % | Composition (weight percent), Specifications and Remarks   |
|-----------|----------|------|---------------|-------------------------|--------------------|-------------------|--|
| 76        | 338      | 1965 | 1244          | 1.00-5.10               | 0°                 |                   | Ribbon; black body (at 1336 K) used as reference standard.   |
| 77        | 338      | 1965 | 1339          | 1.00-5.10               | 0°                 |                   | Above specimen and conditions.   |
| 78        | 338      | 1965 | 1413          | 1.00-5.10               | 0°                 |                   | Above specimen and conditions.   |
| 79        | 338      | 1965 | 1629          | 1.00-5.10               | 0°                 |                   | Above specimen and conditions.   |
| 80        | 338      | 1965 | 1833          | 1.00-5.10               | 0°                 |                   | Above specimen and conditions.   |
| 81        | 338      | 1965 | 2002          | 1.00-5.10               | 0°                 |                   | Above specimen and conditions.   |
| 82        | 338      | 1965 | 2160          | 1.00-5.10               | 0°                 |                   | Above specimen and conditions.   |
| 83        | 338      | 1965 | 2327          | 1.00-5.10               | 0°                 |                   | Above specimen and conditions.   |
| 84        | 338      | 1965 | 2441          | 1.00-5.10               | 0°                 |                   | Above specimen and conditions.   |
| 85        | 323      | 1966 | 300           | 0.46-2.00               | 0°                 |                   | Filament (0.25-0.32 mm in dia); baked for 1 hr at 798 K in vacuum, cooled, heated for 5-10 min in vacuum, and cooled; measured in argon (600 mm Hg); data calculated from optical constants. |
| 86        | 323      | 1966 | 1100          | 0.45-2.00               | 0°                 |                   | Above specimen and conditions.   |
| 87        | 323      | 1966 | 1500          | 0.46-2.00               | 0°                 |                   | Above specimen and conditions.   |
| 88        | 323      | 1966 | 2000          | 0.46-2.00               | 0°                 |                   | Above specimen and conditions.   |
| 89        | 323      | 1966 | 2500          | 0.46-2.00               | 0°                 |                   | Above specimen and conditions.   |
| 90        | 331      | 1917 | 2143          | 0.3478-0.5641           | ~0°                | 5                 | Measured in nitrogen; data is mean of three or more measurements.  |
| 91        | 333      | 1962 | 1600          | 0.230-0.269             | ~0°                |                   | Tungsten ribbon; data extracted from smooth curve  |
| 92        | 333      | 1962 | 1800          | 0.229-0.270             | ~0°                |                   | Above specimen and conditions.   |
| 93        | 333      | 1962 | 2000          | 0.229-0.271             | ~0°                |                   | Above specimen and conditions.   |
| 94        | 333      | 1962 | 2200          | 0.231-0.268             | ~0°                |                   | Above specimen and conditions.   |
| 95        | 333      | 1962 | 2400          | 0.231-0.268             | ~0°                |                   | Above specimen and conditions.   |
| 96        | 333      | 1962 | 2600          | 0.231-0.269             | ~0°                |                   | Above specimen and conditions.   |
| 97        | 333      | 1962 | 2800          | 0.229-0.268             | ~0°                |                   | Above specimen and conditions.   |

DATA TABLE NO. 252 NORMAL SPECTRAL EMITTANCE OF TUNGSTEN

[Wavelength,  $\lambda$ ,  $\mu$ ; Emittance,  $\epsilon$ ; Temperature,  $T$ , K]

| $\lambda$       | $\epsilon$ | $\lambda$              | $\epsilon$ | $\lambda$              | $\epsilon$ | $\lambda$               | $\epsilon$ | $\lambda$               | $\epsilon$ | $\lambda$               | $\epsilon$ | $\lambda$       | $\epsilon$ | $\lambda$               | $\epsilon$ | $\lambda$       | $\epsilon$ |
|-----------------|------------|------------------------|------------|------------------------|------------|-------------------------|------------|-------------------------|------------|-------------------------|------------|-----------------|------------|-------------------------|------------|-----------------|------------|
| <u>CURVE 1</u>  |            | <u>CURVE 4 (cont.)</u> |            | <u>CURVE 7 (cont.)</u> |            | <u>CURVE 10 (cont.)</u> |            | <u>CURVE 12 (cont.)</u> |            | <u>CURVE 14 (cont.)</u> |            | <u>CURVE 17</u> |            | <u>CURVE 18 (cont.)</u> |            |                 |            |
| <u>T = 1605</u> |            |                        |            |                        |            |                         |            |                         |            |                         |            | <u>T = 3100</u> |            |                         |            |                 |            |
| 0.4             | 0.478      | 2.0                    | 0.308      | 3.12                   | 0.156      | 2.17                    | 0.246      | 11.25                   | 0.135      | 1.50                    | 0.280      | 0.40            | 0.472*     | 2.40                    | 0.176      |                 |            |
| 0.6             | 0.455      | 3.0                    | 0.270      | 3.35                   | 0.155      | 2.43                    | 0.235      | 12.00                   | 0.140      | 2.00                    | 0.208*     | 0.50            | 0.458      | 2.60                    | 0.164      |                 |            |
| 0.8             | 0.427      | 4.0                    | 0.250      | 3.47                   | 0.150*     | 2.93                    | 0.200      | 13.00                   | 0.160      | 2.50                    | 0.184      | 0.60            | 0.442*     | <u>CURVE 19*</u>        |            |                 |            |
| 0.9             | 0.410      | 5.0                    | 0.243      |                        |            | 3.12                    | 0.195      | 14.50                   | 0.175      | 3.00                    | 0.163*     | 0.70            | 0.426      | <u>T = 1800</u>         |            |                 |            |
| 1.0             | 0.390      |                        |            | <u>CURVE 8</u>         |            | 3.48                    | 0.190      | 15.00                   | 0.170      | 4.00                    | 0.130      | 0.80            | 0.412*     |                         |            |                 |            |
| 2.0             | 0.210      |                        |            | <u>CURVE 5</u>         |            |                         |            |                         |            |                         |            | 0.90            | 0.396*     | 0.25                    | 0.442      |                 |            |
| 3.0             | 0.147      |                        |            | <u>T = 1830</u>        |            | 1.12                    | 0.390      |                         |            |                         |            | 1.00            | 0.380*     | 0.27                    | 0.471      |                 |            |
| 4.0             | 0.123      | 0.5                    | 0.450      |                        |            | 1.45                    | 0.300      |                         |            |                         |            | 1.50            | 0.318      | 0.30                    | 0.478      |                 |            |
| 5.0             | 0.113      | 1.0                    | 0.380*     |                        |            | 1.70                    | 0.260      | 2.00                    | 0.130      | 1.00                    | 0.590      | 0.40            | 0.510      | 2.00                    | 0.290      | 0.32            | 0.476      |
|                 |            | 1.5                    | 0.295      |                        |            | 2.00                    | 0.220      | 2.50                    | 0.100      | 1.20                    | 0.675      | 0.50            | 0.488      | 2.50                    | 0.272      | 0.35            | 0.476      |
|                 |            | <u>CURVE 2</u>         |            | 2.0                    | 0.218      | 2.22                    | 0.208      | 3.00                    | 0.085      | 1.40                    | 0.700      | 0.60            | 0.466      | 3.00                    | 0.262      | 0.37            | 0.479      |
|                 |            | <u>T = 2140</u>        |            | 2.5                    | 0.170      | 2.42                    | 0.195      | 3.50                    | 0.070      | 1.50                    | 0.710      | 0.70            | 0.445      | 4.00                    | 0.252      | 0.40            | 0.478      |
| 0.4             | 0.470      |                        |            | 3.0                    | 0.146      | 2.92                    | 0.165*     | 4.00                    | 0.060      | 2.00                    | 0.700      | 0.80            | 0.425*     |                         |            | 0.45            | 0.470      |
| 0.6             | 0.445      | 3.5                    | 0.138      |                        |            | 3.13                    | 0.164      | 4.50                    | 0.050      | 2.50                    | 0.720      | 0.90            | 0.404      | <u>CURVE 18</u>         |            | 0.50            | 0.466      |
| 0.8             | 0.422      |                        |            | <u>CURVE 6</u>         |            | 3.48                    | 0.156      | 6.00                    | 0.040      | 3.50                    | 0.775      | 1.00            | 0.381*     | <u>T = 1600</u>         |            | 0.55            | 0.460      |
| 1.0             | 0.387      |                        |            | <u>T = 2040</u>        |            |                         |            | 9.50                    | 0.040      | 4.50                    | 0.805      | 1.42            | 0.306*     |                         |            | 0.60            | 0.452      |
| 2.0             | 0.237      |                        |            |                        |            | <u>CURVE 9</u>          |            | 12.75                   | 0.035      | 5.00                    | 0.825      | 1.50            | 0.282*     | 0.25                    | 0.448      | 0.65            | 0.446      |
| 3.0             | 0.177      | 0.5                    | 0.440      |                        |            | 1.55                    | 0.310      | 14.50                   | 0.030      | 6.00                    | 0.800      | 2.00            | 0.236*     | 0.27                    | 0.476      | 0.70            | 0.440      |
| 4.0             | 0.150      | 1.0                    | 0.365      |                        |            | 1.13                    | 0.382      | 15.00                   | 0.020      | 6.50                    | 0.805      | 2.50            | 0.220      | 0.30                    | 0.482      | 0.75            | 0.434      |
| 5.0             | 0.145      | 1.5                    | 0.293      |                        |            | 1.55                    | 0.310      |                         |            | 7.25                    | 0.845      | 3.00            | 0.204*     | 0.32                    | 0.478      | 0.80            | 0.426      |
|                 |            | 2.0                    | 0.244      |                        |            | 1.62                    | 0.285      |                         |            | 8.00                    | 0.880      | 4.00            | 0.180*     | 0.35                    | 0.479      | 0.90            | 0.406      |
|                 |            | <u>CURVE 3</u>         |            | 2.5                    | 0.195      | 1.70                    | 0.263*     |                         |            | 9.50                    | 0.865      |                 |            | 0.37                    | 0.482      | 1.00            | 0.386      |
|                 |            | <u>T = 2639</u>        |            | 3.0                    | 0.165      | 1.85                    | 0.255      | 1.00                    | 0.960      | 10.00                   | 0.835      | <u>CURVE 16</u> |            | 0.40                    | 0.481      | 1.20            | 0.345      |
|                 |            |                        |            | 3.5                    | 0.150      | 1.94                    | 0.250      | 1.05                    | 0.900      | 11.00                   | 0.610      | <u>T = 2800</u> |            | 0.42                    | 0.478      | 1.27            | 0.328      |
| 0.4             | 0.455      |                        |            |                        |            | 2.14                    | 0.228      | 1.20                    | 0.850      | 12.00                   | 0.550      | 0.40            | 0.478*     | 0.45                    | 0.474      | 1.35            | 0.312      |
| 0.6             | 0.430      |                        |            | <u>CURVE 7</u>         |            | 2.25                    | 0.221      | 1.50                    | 0.815      | 12.75                   | 0.580      | 0.50            | 0.467      | 0.55                    | 0.464      | 1.60            | 0.269      |
| 0.8             | 0.403      |                        |            | <u>T = 1316</u>        |            | 2.43                    | 0.225      | 2.00                    | 0.830      | 13.50                   | 0.580      | 0.60            | 0.450      | 0.60                    | 0.456*     | 1.80            | 0.242      |
| 1.0             | 0.375      |                        |            |                        |            | 2.68                    | 0.193      | 2.50                    | 0.820      | 14.50                   | 0.570      | 0.70            | 0.430      | 0.65                    | 0.450      | 2.40            | 0.187      |
| 2.0             | 0.258      | 1.10                   | 0.465      |                        |            | 2.92                    | 0.185      | 3.00                    | 0.800      | 15.00                   | 0.550      | 0.80            | 0.412      | 0.70                    | 0.444*     | 2.60            | 0.175      |
| 3.0             | 0.205      | 1.27                   | 0.345      |                        |            | 3.12                    | 0.183      | 3.50                    | 0.805      |                         |            | 0.90            | 0.393      | 0.75                    | 0.438      |                 |            |
| 4.0             | 0.183      | 1.47                   | 0.290      |                        |            | 3.33                    | 0.175      | 4.00                    | 0.810      | <u>CURVE 14</u>         |            | 1.00            | 0.367      | 0.80                    | 0.432      | <u>CURVE 20</u> |            |
| 5.0             | 0.180      | 1.67                   | 0.260      |                        |            | 3.62                    | 0.172      | 4.50                    | 0.765      | <u>T = 1600</u>         |            | 1.42            | 0.306*     | 0.90                    | 0.412*     | <u>T = 2000</u> |            |
|                 |            | 1.86                   | 0.225      |                        |            | 3.84                    | 0.170      | 4.75                    | 0.715      |                         |            | 1.50            | 0.294*     | 1.00                    | 0.390*     |                 |            |
|                 |            | <u>CURVE 4</u>         |            | 2.05                   | 0.208      | 4.04                    | 0.169      | 5.00                    | 0.650      | 0.50                    | 0.500      | 2.00            | 0.267      | 1.20                    | 0.344      | 0.25            | 0.436      |
|                 |            | <u>T = 2650</u>        |            | 2.24                   | 0.195      |                         |            | 5.50                    | 0.560      | 0.60                    | 0.478      | 2.50            | 0.252      | 1.27                    | 0.328      | 0.27            | 0.466      |
| 0.4             | 0.433      | 2.40                   | 0.185      |                        |            | 6.00                    | 0.480      | 0.70                    | 0.457      | 3.00                    | 0.240      | 1.35            | 0.310      | 0.30                    | 0.470      |                 |            |
| 0.5             | 0.430      | 2.50                   | 0.175      |                        |            | 7.00                    | 0.360      | 0.80                    | 0.437      | 4.00                    | 0.228      | 1.50            | 0.280*     | 0.32                    | 0.472      |                 |            |
| 0.6             | 0.425      | 2.70                   | 0.174      |                        |            | 7.75                    | 0.305      | 0.90                    | 0.415      |                         |            | 1.60            | 0.263      | 0.35                    | 0.473      |                 |            |
| 0.8             | 0.405      | 2.82                   | 0.167      | 1.16                   | 0.373      | 9.00                    | 0.200      | 1.00                    | 0.390*     |                         |            | 1.80            | 0.234      | 0.37                    | 0.476      |                 |            |
| 1.0             | 0.383      | 2.97                   | 0.165      | 1.68                   | 0.299      | 10.00                   | 0.150      | 1.15                    | 0.360      |                         |            | 2.00            | 0.210*     | 0.40                    | 0.474*     |                 |            |
|                 |            | 3.10                   | 0.160      | 1.99                   | 0.263      | 10.75                   | 0.150      | 1.42                    | 0.306      |                         |            | 2.20            | 0.190      | 0.45                    | 0.467      |                 |            |

\* Not shown on plot

DATA TABLE NO. 252 (continued)

| $\lambda$               | $\epsilon$ | $\lambda$        | $\epsilon$ | $\lambda$               | $\epsilon$ | $\lambda$               | $\epsilon$ | $\lambda$               | $\epsilon$ | $\lambda$               | $\epsilon$ | $\lambda$               | $\epsilon$ | $\lambda$               | $\epsilon$ |
|-------------------------|------------|------------------|------------|-------------------------|------------|-------------------------|------------|-------------------------|------------|-------------------------|------------|-------------------------|------------|-------------------------|------------|
| <u>CURVE 20 (cont.)</u> |            | <u>CURVE 22</u>  |            | <u>CURVE 23 (cont.)</u> |            | <u>CURVE 25 (cont.)</u> |            | <u>CURVE 26 (cont.)</u> |            | <u>CURVE 27 (cont.)</u> |            | <u>CURVE 29 (cont.)</u> |            | <u>CURVE 30 (cont.)</u> |            |
|                         |            | T = 2000         |            | T = 2400                |            |                         |            |                         |            |                         |            |                         |            |                         |            |
| 0.50                    | 0.462      | 0.25             | 0.422      | 1.20                    | 0.339      | 0.340                   | 0.481      | 0.520                   | 0.453      | 0.740                   | 0.422      | 0.340                   | 0.472      | 6.45                    | 0.065      |
| 0.55                    | 0.456      | 0.27             | 0.456      | 1.32                    | 0.328      | 0.360                   | 0.480      | 0.540                   | 0.451      | 0.760                   | 0.420      | 0.350                   | 0.472      | 7.20                    | 0.060      |
| 0.60                    | 0.448*     | 0.30             | 0.465      | 1.40                    | 0.317      | 0.370                   | 0.479*     | 0.460                   | 0.449      | 0.780                   | 0.418      | 0.360                   | 0.471      | 7.60                    | 0.060      |
| 0.65                    | 0.442      | 0.32             | 0.465      | 1.50                    | 0.299      | 0.380                   | 0.477*     | 0.580                   | 0.447      | 0.800                   | 0.416      | 0.370                   | 0.470      | 8.90                    | 0.060      |
| 0.75                    | 0.428      | 0.35             | 0.467      | 1.60                    | 0.288      | 0.390                   | 0.475      | 0.600                   | 0.444      |                         |            | 0.380                   | 0.469      | 10.00                   | 0.060      |
| 0.80                    | 0.420*     | 0.37             | 0.470      | 1.80                    | 0.268      | 0.400                   | 0.473*     | 0.620                   | 0.441      |                         |            |                         |            |                         |            |
| 0.90                    | 0.400*     | 0.40             | 0.468*     | 2.40                    | 0.224      | 0.420                   | 0.469      | 0.640                   | 0.438      |                         |            |                         |            |                         |            |
| 1.00                    | 0.382*     | 0.45             | 0.460      | 2.60                    | 0.214      | 0.440                   | 0.465      | 0.660                   | 0.436      |                         |            |                         |            |                         |            |
| 1.20                    | 0.342*     | 0.50             | 0.455*     |                         |            | 0.480                   | 0.459      | 0.700                   | 0.433      | 0.320                   | 0.473      | 0.460                   | 0.456      | <u>CURVE 31</u>         |            |
| 1.27                    | 0.328*     | 0.55             | 0.450      | <u>CURVE 24</u>         |            | 0.500                   | 0.457*     | 0.720                   | 0.429      | 0.330                   | 0.474      | 0.480                   | 0.452      | <u>T = 1428</u>         |            |
| 1.35                    | 0.313*     | 0.60             | 0.440*     | <u>T = 2800</u>         |            | 0.520                   | 0.455      | 0.740                   | 0.426      | 0.340                   | 0.474      | 0.500                   | 0.449      | 0.50                    | 0.456*     |
| 1.50                    | 0.288*     | 0.65             | 0.434      |                         |            | 0.540                   | 0.453*     | 0.760                   | 0.423      | 0.350                   | 0.474      | 0.520                   | 0.446      | 0.60                    | 0.445*     |
| 1.60                    | 0.273      | 0.70             | 0.428*     | 0.25                    | 0.410      | 0.560                   | 0.452      | 0.780                   | 0.421      | 0.360                   | 0.473      | 0.540                   | 0.443      | 0.70                    | 0.428*     |
| 1.80                    | 0.247      | 0.75             | 0.418      | 0.27                    | 0.445      | 0.580                   | 0.450      | 0.800                   | 0.419      | 0.370                   | 0.472      | 0.560                   | 0.441      | 1.00                    | 0.380*     |
| 2.40                    | 0.196*     | 0.80             | 0.409*     | 0.30                    | 0.456      | 0.600                   | 0.447      |                         |            | 0.380                   | 0.471      | 0.580                   | 0.437      | 1.50                    | 0.275      |
| 2.60                    | 0.187      | 0.90             | 0.396*     | 0.32                    | 0.457      | 0.620                   | 0.445      |                         |            |                         |            | 0.600                   | 0.434      | 2.00                    | 0.225*     |
|                         | 1.00       | 0.373*           |            | 0.35                    | 0.461      | 0.640                   | 0.442*     |                         |            |                         |            | 0.400                   | 0.468      | 0.620                   | 0.430      |
| <u>CURVE 21*</u>        |            | 1.20             | 0.339      | 0.37                    | 0.463      | 0.660                   | 0.441      |                         |            |                         |            | 0.420                   | 0.464      | 0.640                   | 0.426      |
| <u>T = 2200</u>         |            | 1.32             | 0.328      | 0.40                    | 0.461      | 0.680                   | 0.440*     | 0.310                   | 0.474      |                         |            | 0.440                   | 0.461      | 0.660                   | 0.424      |
|                         | 1.40       | 0.313            | 0.45       | 0.454*                  | 0.700      | 0.437                   | 0.320      | 0.476                   | 0.460      | 0.457                   | 0.680      | 0.421                   | 3.50       | 0.110                   |            |
| 0.25                    | 0.430      | 1.50             | 0.288*     | 0.50                    | 0.448*     | 0.720                   | 0.434      | 0.330                   | 0.477      | 0.480                   | 0.454      | 0.700                   | 0.419      | 4.50                    | 0.090      |
| 0.27                    | 0.460      | 1.60             | 0.273*     | 0.55                    | 0.443      | 0.740                   | 0.430      | 0.340                   | 0.477      | 0.500                   | 0.451      | 0.720                   | 0.417      | 5.65                    | 0.085      |
| 0.30                    | 0.470      | 1.80             | 0.247*     | 0.60                    | 0.434      | 0.760                   | 0.427*     | 0.350                   | 0.476      | 0.520                   | 0.448      | 0.740                   | 0.415      | 7.00                    | 0.080      |
| 0.32                    | 0.468      | 2.40             | 0.196*     | 0.65                    | 0.427      | 0.780                   | 0.424      | 0.360                   | 0.475      | 0.540                   | 0.446      | 0.760                   | 0.413      | 8.00                    | 0.080      |
| 0.35                    | 0.470      | 2.60             | 0.185*     | 0.70                    | 0.419      | 0.800                   | 0.422*     | 0.370                   | 0.474      | 0.560                   | 0.443      | 0.780                   | 0.412      | 9.00                    | 0.080      |
| 0.37                    | 0.473      |                  |            | 0.75                    | 0.410      |                         |            | 0.380                   | 0.473      | 0.580                   | 0.440      | 0.800                   | 0.411      | 10.00                   | 0.080      |
| 0.40                    | 0.470      | <u>CURVE 23*</u> |            | 0.80                    | 0.400      | <u>CURVE 26*</u>        |            | 0.390                   | 0.471      | 0.600                   | 0.437      |                         |            | 11.00                   | 0.080      |
| 0.45                    | 0.464      | <u>T = 2600</u>  |            | 0.90                    | 0.373      | <u>T = 1800</u>         |            | 0.400                   | 0.469      | 0.620                   | 0.433      | <u>CURVE 30</u>         |            | 12.00                   | 0.080      |
| 0.50                    | 0.458      | 1.00             | 0.367*     |                         |            | 0.420                   | 0.466      | 0.640                   | 0.430      | <u>T = 1200</u>         |            |                         |            |                         |            |
| 0.55                    | 0.453      | 0.25             | 0.416      | 1.20                    | 0.337*     | 0.310                   | 0.476      | 0.440                   | 0.462      | 0.660                   | 0.428      | <u>CURVE 32</u>         |            |                         |            |
| 0.60                    | 0.444      | 0.27             | 0.450      | 1.32                    | 0.328*     | 0.320                   | 0.479      | 0.460                   | 0.459      | 0.680                   | 0.426      | 0.50                    | 0.465*     | <u>T = 1972</u>         |            |
| 0.65                    | 0.438      | 0.30             | 0.460      | 1.35                    | 0.318      | 0.330                   | 0.480      | 0.480                   | 0.456      | 0.700                   | 0.424      | 0.66                    | 0.450*     |                         |            |
| 0.70                    | 0.432      | 0.33             | 0.461      | 1.50                    | 0.302      | 0.340                   | 0.479      | 0.500                   | 0.453      | 0.720                   | 0.421      | 0.70                    | 0.445*     | 0.45                    | 0.455*     |
| 0.75                    | 0.423      | 0.35             | 0.466      | 1.60                    | 0.292      | 0.350                   | 0.479      | 0.520                   | 0.450      | 0.740                   | 0.419      | 1.00                    | 0.380*     | 0.50                    | 0.446*     |
| 0.80                    | 0.414      | 0.40             | 0.464      | 1.80                    | 0.271      | 0.360                   | 0.478      | 0.540                   | 0.448      | 0.760                   | 0.416      | 1.80                    | 0.210      | 0.55                    | 0.444*     |
| 0.90                    | 0.396      | 0.45             | 0.457      | 2.40                    | 0.233*     | 0.370                   | 0.476      | 0.560                   | 0.446      | 0.780                   | 0.415      | 2.50                    | 0.140      | 0.60                    | 0.440*     |
| 1.00                    | 0.377      | 0.50             | 0.451      | 2.60                    | 0.224      | 0.380                   | 0.475      | 0.580                   | 0.443      | 0.800                   | 0.413      | 2.75                    | 0.125      | 0.65                    | 0.433*     |
| 1.20                    | 0.340      | 0.55             | 0.446      |                         |            | 0.390                   | 0.473      | 0.600                   | 0.440      |                         |            | 3.00                    | 0.110      | 0.70                    | 0.423*     |
| 1.32                    | 0.328      | 0.60             | 0.438      | <u>CURVE 25</u>         |            | 0.400                   | 0.471      | 0.620                   | 0.437      | <u>CURVE 29*</u>        |            | 3.25                    | 0.100      | 0.80                    | 0.410*     |
| 1.50                    | 0.284      | 0.65             | 0.430      | <u>T = 1600</u>         |            | 0.420                   | 0.467      | 0.640                   | 0.434      | <u>T = 2400</u>         |            | 3.50                    | 0.090      | 1.50                    | 0.275*     |
| 1.60                    | 0.278      | 0.70             | 0.423      |                         |            | 0.440                   | 0.463      | 0.660                   | 0.432      |                         |            | 3.90                    | 0.085      | 2.00                    | 0.225*     |
| 1.80                    | 0.255      | 0.75             | 0.414      | 0.310                   | 0.479      | 0.460                   | 0.460      | 0.680                   | 0.430      | 0.310                   | 0.468      | 4.50                    | 0.075      | 2.50                    | 0.175*     |
| 2.40                    | 0.205      | 0.80             | 0.404      | 0.320                   | 0.482      | 0.480                   | 0.457      | 0.700                   | 0.428      | 0.320                   | 0.471      | 5.00                    | 0.075      | 3.00                    | 0.155      |
| 2.60                    | 0.195      | 0.90             | 0.388      | 0.330                   | 0.482      | 0.500                   | 0.455      | 0.720                   | 0.425      | 0.330                   | 0.472      | 5.90                    | 0.070      | 3.50                    | 0.145      |

\* Not shown on plot

DATA TABLE NO. 252 (continued)

| $\lambda$               | $\epsilon$ | $\lambda$                           | $\epsilon$ | $\lambda$                                  | $\epsilon$ | $\lambda$                                  | $\epsilon$ | $\lambda$                          | $\epsilon$ | $\lambda$                           | $\epsilon$ | $\lambda$                           | $\epsilon$ | $\lambda$                          | $\epsilon$ |
|-------------------------|------------|-------------------------------------|------------|--|------------|--|------------|------------------------------------|------------|-------------------------------------|------------|-------------------------------------|------------|------------------------------------|------------|
| <u>CURVE 32 (cont.)</u> |            | <u>CURVE 36*</u><br><u>T = 1972</u> |            | <u>CURVE 39 (cont.)</u><br><u>T = 2050</u> |            | <u>CURVE 43 (cont.)*</u><br><u>T = 860</u> |            | <u>CURVE 48*</u><br><u>T = 702</u> |            | <u>CURVE 52*</u><br><u>T = 1378</u> |            | <u>CURVE 57*</u><br><u>T = 1214</u> |            | <u>CURVE 61</u><br><u>T = 700</u>  |            |
| 4.00                    | 0.140      | 0.90                                | 0.384      | 6  | 0.188      | 6  | 0.057      | 1.5                                | 0.24       | 0.65                                | 0.46       | 0.65                                | 0.59       | 1.5                                | 0.47       |
| 5.00                    | 0.120      | 0.95                                | 0.368      | 8  | 0.140      | 8  | 0.043      | 2                                  | 0.13       | 1.5                                 | 0.22       | 1                                   | 0.70       | 2                                  | 0.43       |
| 6.00                    | 0.110      | 1.00                                | 0.365      | 10   | 0.118      | 10   | 0.034      | 4                                  | 0.060      | 2                                   | 0.14       | 1.5                                 | 0.61       | 4                                  | 0.37       |
| 7.00                    | 0.100      | 1.05                                | 0.354      | 12   | 0.104      |  |            | 6                                  | 0.046      | 4                                   | 0.11       | 2                                   | 0.55       | 6                                  | 0.34*      |
|                         |            | 1.10                                | 0.343      |  |            | <u>CURVE 40*</u><br><u>T = 1200</u>        |            | 8                                  | 0.035      |                                     |            | 4                                   | 0.46       | 8                                  | 0.30       |
|                         |            | <u>CURVE 33*</u><br><u>T = 1660</u> |            | 1.20                                       | 0.324      |  |            | 10                                 | 0.026      | <u>CURVE 53*</u><br><u>T = 1603</u> |            | 6                                   | 0.41       | 10                                 | 0.27       |
|                         |            |                                     |            | 1.25                                       | 0.317      |  |            | 1.5                                | 0.41       |                                     |            | 8                                   | 0.37       | 12                                 | 0.25       |
|                         |            |                                     |            | 1.30                                       | 0.306      | 0.65                                       | 0.67       | 2                                  | 0.25       | <u>CURVE 49*</u><br><u>T = 870</u>  |            | 10                                  | 0.34       |                                    |            |
| 1.10                    | 0.340      | 1.40                                | 0.296      | 1  | 0.73       | 4  | 0.10       |                                    |            | 0.65                                | 0.52       | 12                                  | 0.30       |                                    |            |
| 1.20                    | 0.332      | 1.45                                | 0.280      | 1.5  | 0.61       | 6  | 0.071      |                                    |            | 1.5                                 | 0.29       |                                     |            | <u>CURVE 62*</u><br><u>T = 858</u> |            |
| 1.30                    | 0.314      | 1.50                                | 0.277      | 2  | 0.52       | 8  | 0.059      | 1.5                                | 0.26       | 2                                   | 0.21       |                                     |            |                                    |            |
| 1.40                    | 0.300      | 1.55                                | 0.270      | 4  | 0.29       | 10   | 0.050      | 2                                  | 0.15       | 4                                   | 0.18       | <u>CURVE 58*</u><br><u>T = 1383</u> |            | 1.5                                | 0.53       |
| 1.50                    | 0.276      | 1.60                                | 0.262      | 6  | 0.185      |  |            | 4                                  | 0.074      |                                     |            |                                     |            | 2                                  | 0.45       |
| 1.55                    | 0.272      | 1.70                                | 0.250      | 8  | 0.143      | <u>CURVE 45*</u><br><u>T = 1029</u>        |            | 6                                  | 0.056      | <u>CURVE 54</u><br><u>T = 692</u>   |            | 0.65                                | 0.52       | 4                                  | 0.39       |
| 1.60                    | 0.260      |                                     |            | 10   | 0.119      |  |            | 8                                  | 0.048      |                                     |            | 1                                   | 0.56       | 6                                  | 0.35       |
| 1.70                    | 0.243      |                                     |            | 12   | 0.103      |  |            | 10                                 | 0.044      |                                     |            | 1.5                                 | 0.48       | 8                                  | 0.31       |
|                         |            | <u>CURVE 37</u><br><u>T = 693</u>   |            |  |            | 1  | 0.55       |                                    |            | 2                                   | 0.56       | 2                                   | 0.45       | 10                                 | 0.28       |
|                         |            | <u>CURVE 34*</u><br><u>T = 1790</u> |            | 1.5  | 0.57       | <u>CURVE 41</u><br><u>T = 1373</u>         |            | 1.5                                | 0.40       | <u>CURVE 50*</u><br><u>T = 1039</u> |            | 4                                   | 0.45       | 4                                  | 0.40       |
|                         |            |                                     |            | 2  | 0.54       |  |            | 2                                  | 0.25       |                                     |            | 6                                   | 0.34       | 6                                  | 0.36       |
| 0.9                     | 0.394      | 4                                   | 0.28       | 0.65                                       | 0.57       |  |            | 4                                  | 0.110      |                                     |            | 8                                   | 0.34       | 8                                  | 0.32       |
| 1.0                     | 0.370      | 6                                   | 0.165      | 1  | 0.65       | 6  | 0.081      | 1.5                                | 0.32       | 10                                  | 0.30       | 10                                  | 0.30       |                                    |            |
| 1.1                     | 0.353      | 8                                   | 0.118      | 1.5  | 0.50       | 8  | 0.067      | 2                                  | 0.18       |                                     |            | 12                                  | 0.27       | <u>CURVE 63</u><br><u>T = 1198</u> |            |
| 1.2                     | 0.330      | 10                                  | 0.088      | 2  | 0.39       | 10   | 0.058      | 4                                  | 0.088      | <u>CURVE 55*</u><br><u>T = 863</u>  |            |                                     |            | 0.65                               | 0.60       |
| 1.3                     | 0.312      |                                     |            | 4  | 0.21       |  |            | 6                                  | 0.069      |                                     |            | <u>CURVE 59*</u><br><u>T = 699</u>  |            | 1.5                                | 0.54       |
| 1.4                     | 0.306      | <u>CURVE 38</u><br><u>T = 860</u>   |            | 6  | 0.141      | <u>CURVE 46</u><br><u>T = 1196</u>         |            | 10                                 | 0.055      | 1.5                                 | 0.61       |                                     |            | 4                                  | 0.40       |
| 1.5                     | 0.275      |                                     |            | 8  | 0.119*     |  |            | 12                                 | 0.050      | 2                                   | 0.54       | 1.5                                 | 0.46       | 6                                  | 0.36       |
| 1.6                     | 0.258      |                                     |            | 10   | 0.090      |  |            |                                    |            | 4                                   | 0.45       | 2                                   | 0.41       | 8                                  | 0.33       |
| 1.7                     | 0.249      | 1.5                                 | 0.64       | 12   | 0.096      | 1  | 0.62       | <u>CURVE 51</u><br><u>T = 1208</u> |            | 6                                   | 0.40       | 4                                   | 0.36       | 10                                 | 0.30*      |
|                         |            |                                     |            | 2  | 0.52       | 1.5  | 0.42       |                                    |            | 8                                   | 0.35       | 6                                   | 0.32       | 12                                 | 0.27       |
|                         |            | <u>CURVE 35*</u><br><u>T = 1950</u> |            | 4  | 0.29       | <u>CURVE 42*</u><br><u>T = 1603</u>        |            | 2                                  | 0.29       |                                     |            | 10                                  | 0.28       | 8                                  | 0.29       |
|                         |            |                                     |            | 6  | 0.181      |  |            | 4                                  | 0.129*     | 0.65                                | 0.54       | 12                                  | 0.28       | 10                                 | 0.26       |
|                         |            |                                     |            | 8  | 0.130      |  |            | 6                                  | 0.095      | 1                                   | 0.46       |                                     |            | <u>CURVE 64</u><br><u>T = 1358</u> |            |
| 0.90                    | 0.403      | 10                                  | 0.107      | 0.65                                       | 0.58       | 8  | 0.050      | 1.5                                | 0.27       | <u>CURVE 56</u><br><u>T = 1040</u>  |            |                                     |            | 0.65                               | 0.56       |
| 1.00                    | 0.374      | 12                                  | 0.085      | 1.5  | 0.38       | 10   | 0.070      | 2                                  | 0.17       |                                     |            |                                     |            | 1                                  | 0.60       |
| 1.10                    | 0.358      |                                     |            | 2  | 0.28       | 12   | 0.063      | 4                                  | 0.093      |                                     |            |                                     |            |                                    |            |
| 1.20                    | 0.332      | <u>CURVE 39</u><br><u>T = 1033</u>  |            | 4  | 0.18       |  |            | 6                                  | 0.077      | 1.5                                 | 0.60       | 1.5                                 | 0.49       | 1.5                                | 0.52       |
| 1.25                    | 0.320      |                                     |            |  |            | <u>CURVE 47*</u><br><u>T = 1378</u>        |            | 8                                  | 0.068      | 2                                   | 0.47       | 2                                   | 0.44       | 2                                  | 0.49       |
| 1.30                    | 0.316      |                                     |            |  |            |  |            | 10                                 | 0.072      | 4                                   | 0.45*      | 4                                   | 0.37       | 4                                  | 0.44       |
| 1.40                    | 0.304      | 0.65                                | 0.66       |  |            | <u>CURVE 43*</u><br><u>T = 693</u>         |            | 12                                 | 0.058      | 6                                   | 0.40       | 6                                   | 0.33       | 6                                  | 0.40*      |
| 1.50                    | 0.282      | 1                                   | 0.73       |  |            | 1.5  | 0.32       |                                    |            | 8                                   | 0.36       | 8                                   | 0.30       | 8                                  | 0.36*      |
| 1.55                    | 0.277      | 1.5                                 | 0.62       | 1.5  | 0.36       | 2  | 0.25       |                                    |            | 10                                  | 0.32       | 10                                  | 0.26       | 10                                 | 0.33       |
| 1.60                    | 0.267      | 2                                   | 0.52       | 2  | 0.21       | 4  | 0.16       |                                    |            | 12                                  | 0.29       |                                     |            | 12                                 | 0.31       |
| 1.70                    | 0.257      | 4                                   | 0.29       | 4  | 0.082      |  |            |                                    |            |                                     |            |                                     |            |                                    |            |

\* Not shown on plot

DATA TABLE NO. 252 (continued)

| $\lambda$ | $\epsilon$ | $\lambda$        | $\epsilon$ | $\lambda$        | $\epsilon$ | $\lambda$ | $\epsilon$ | $\lambda$       | $\epsilon$ | $\lambda$        | $\epsilon$ | $\lambda$        | $\epsilon$ | $\lambda$        | $\epsilon$ |
|-----------|------------|------------------|------------|------------------|------------|-----------|------------|-----------------|------------|------------------|------------|------------------|------------|------------------|------------|
| CURVE 65* |            | CURVE 68(cont.)* |            | CURVE 71(cont.)* |            | CURVE 75* |            | CURVE 76(cont.) |            | CURVE 77(cont.)* |            | CURVE 78(cont.)* |            | CURVE 79(cont.)* |            |
| T = 1600  |            | T = 3100         |            | T = 1340         |            | T = 2520  |            | T = 1244        |            | T = 1339         |            | T = 1413         |            | T = 1629         |            |
| 0.50      | 0.495      | 1.50             | 0.320      | 2.420            | 0.193      | 0.467     | 0.454      | 4.00            | 0.063      | 3.80             | 0.076      | 3.60             | 0.089      | 3.40             | 0.114      |
| 0.70      | 0.450      | 2.00             | 0.291      | 2.919            | 0.165      | 0.499     | 0.452      | 4.20            | 0.058      | 4.00             | 0.071      | 3.80             | 0.083      | 3.60             | 0.107      |
| 0.90      | 0.410      | 3.00             | 0.260      | 3.121            | 0.164      | 0.548     | 0.446      | 4.40            | 0.053      | 4.20             | 0.066      | 4.00             | 0.077      | 3.80             | 0.100      |
| 1.15      | 0.360      | 4.00             | 0.240      | 3.485            | 0.159      | 0.578     | 0.441      | 4.60            | 0.049      | 4.40             | 0.061      | 4.20             | 0.072      | 4.00             | 0.094      |
| 1.50      | 0.290      |                  |            |                  |            | 0.654     | 0.429      | 4.80            | 0.045      | 4.60             | 0.057      | 4.40             | 0.067      | 4.20             | 0.088      |
| 1.72      | 0.240      | CURVE 69*        |            | CURVE 72*        |            | 0.698     | 0.423      | 5.00            | 0.041      | 4.80             | 0.053      | 4.60             | 0.062      | 4.40             | 0.083      |
| 2.00      | 0.210      | T = 1429         |            | T = 1316         |            |           |            | 5.10            | 0.039      | 5.00             | 0.048      | 4.80             | 0.058      | 4.60             | 0.078      |
| 2.10      | 0.200      |                  |            |                  |            | CURVE 76  |            |                 |            | 5.10             | 0.047      | 5.00             | 0.054      | 4.80             | 0.074      |
| 2.50      | 0.185      | 1.157            | 0.378      | 1.096            | 0.464      | T = 1244  |            | CURVE 77*       |            |                  |            | 5.10             | 0.052      | 5.00             | 0.070      |
| 4.00      | 0.128      | 1.676            | 0.298      | 1.264            | 0.345      |           |            | T = 1339        |            | CURVE 78*        |            |                  |            | 5.10             | 0.068      |
|           |            | 1.984            | 0.261      | 1.457            | 0.290      | 1.00      | 0.402      |                 |            | T = 1413         |            | CURVE 79*        |            |                  |            |
|           |            | CURVE 66*        |            | 2.164            | 0.246      | 1.655     | 0.259      | 1.05            | 0.389      | T = 1629         |            |                  |            |                  |            |
|           |            | T = 2000         |            | 2.416            | 0.235      | 1.860     | 0.224      | 1.10            | 0.373      | T = 1833         |            | CURVE 80*        |            |                  |            |
|           |            |                  |            | 2.929            | 0.199      | 2.049     | 0.206      | 1.15            | 0.360      |                  |            |                  |            |                  |            |
| 0.40      | 0.505      | 3.122            | 0.194      | 2.231            | 0.194      | 1.20      | 0.345      | 1.15            | 0.358      | 1.10             | 0.368      | 1.05             | 0.377      | 1.00             | 0.382      |
| 0.50      | 0.480      | 3.486            | 0.189      | 2.389            | 0.182      | 1.24      | 0.333      | 1.20            | 0.344      | 1.15             | 0.357      | 1.10             | 0.364      | 1.05             | 0.372      |
| 0.70      | 0.440      |                  |            | 2.539            | 0.175      | 1.30      | 0.318      | 1.24            | 0.333      | 1.20             | 0.343      | 1.15             | 0.354      | 1.10             | 0.361      |
| 0.90      | 0.400      | CURVE 70*        |            | 2.694            | 0.171      | 1.35      | 0.305      | 1.30            | 0.319      | 1.24             | 0.333      | 1.20             | 0.342      | 1.15             | 0.352      |
| 1.15      | 0.350      | T = 1382         |            | 2.823            | 0.167      | 1.40      | 0.292      | 1.35            | 0.306      | 1.30             | 0.320      | 1.24             | 0.333      | 1.20             | 0.342      |
| 1.50      | 0.290      |                  |            | 2.970            | 0.165      | 1.45      | 0.280      | 1.40            | 0.294      | 1.35             | 0.308      | 1.30             | 0.321      | 1.24             | 0.333      |
| 1.75      | 0.260      | 1.127            | 0.382      | 3.092            | 0.158      | 1.50      | 0.269*     | 1.45            | 0.283      | 1.40             | 0.296      | 1.35             | 0.311      | 1.30             | 0.322      |
| 2.00      | 0.240      | 1.551            | 0.302      | 3.220            | 0.154      | 1.55      | 0.259      | 1.50            | 0.272      | 1.45             | 0.286      | 1.40             | 0.301      | 1.35             | 0.313      |
| 2.50      | 0.220      | 1.615            | 0.286      | 3.340            | 0.154      | 1.60      | 0.249      | 1.55            | 0.262      | 1.50             | 0.275      | 1.45             | 0.292      | 1.40             | 0.304      |
| 4.00      | 0.180      | 1.693            | 0.272      | 3.459            | 0.150      | 1.65      | 0.240      | 1.60            | 0.253      | 1.55             | 0.265      | 1.50             | 0.282      | 1.45             | 0.296      |
|           |            | 1.846            | 0.255      |                  |            | 1.70      | 0.231      | 1.65            | 0.244      | 1.60             | 0.256      | 1.55             | 0.274      | 1.50             | 0.288      |
|           |            | CURVE 67*        |            | 1.934            | 0.252      | CURVE 73* |            | 1.75            | 0.222      | 1.70             | 0.236      | 1.65             | 0.248      | 1.60             | 0.265      |
|           |            | T = 2800         |            | 2.135            | 0.229      | T = 1800  |            | 1.80            | 0.214      | 1.75             | 0.227      | 1.70             | 0.240      | 1.65             | 0.257      |
|           |            |                  |            | 2.239            | 0.223      |           |            | 1.85            | 0.206      | 1.80             | 0.219      | 1.75             | 0.232      | 1.70             | 0.250      |
| 0.40      | 0.480      | 2.422            | 0.224      | 0.467            | 0.470      | 1.90      | 0.198      | 1.85            | 0.212      | 1.80             | 0.224      | 1.75             | 0.242      | 1.70             | 0.259      |
| 0.50      | 0.460      | 2.685            | 0.191      | 0.499            | 0.466      | 1.95      | 0.191      | 1.90            | 0.204      | 1.85             | 0.217      | 1.80             | 0.236      | 1.75             | 0.252      |
| 0.70      | 0.425      | 2.919            | 0.184      | 0.548            | 0.460      | 2.00      | 0.184      | 1.95            | 0.197      | 1.90             | 0.209      | 1.85             | 0.229      | 1.80             | 0.245      |
| 0.90      | 0.390      | 3.128            | 0.181      | 0.578            | 0.456      | 2.10      | 0.172      | 2.00            | 0.194      | 1.95             | 0.203      | 1.90             | 0.222      | 1.85             | 0.239      |
| 1.21      | 0.330      | 3.335            | 0.173      | 0.654            | 0.445      | 2.20      | 0.161      | 2.10            | 0.180      | 2.00             | 0.197      | 1.95             | 0.217      | 1.90             | 0.233      |
| 1.50      | 0.295      | 3.627            | 0.171      | 0.698            | 0.441      | 2.30      | 0.150      | 2.20            | 0.169      | 2.10             | 0.186      | 2.00             | 0.210      | 1.95             | 0.227      |
| 2.00      | 0.260      | 3.843            | 0.170      |                  |            | 2.40      | 0.141      | 2.30            | 0.158      | 2.20             | 0.175      | 2.10             | 0.199      | 2.00             | 0.221      |
| 3.00      | 0.231      | 4.038            | 0.169      | CURVE 74*        |            | 2.50      | 0.133      | 2.40            | 0.149      | 2.30             | 0.165      | 2.20             | 0.189      | 2.10             | 0.211      |
| 4.00      | 0.220      |                  |            | T = 2150         |            | 2.60      | 0.124      | 2.50            | 0.141      | 2.40             | 0.156      | 2.30             | 0.180      | 2.20             | 0.201      |
|           |            | CURVE 71*        |            |                  |            | 2.70      | 0.117      | 2.60            | 0.132      | 2.50             | 0.147      | 2.40             | 0.171      | 2.30             | 0.192      |
|           |            | CURVE 68*        |            | T = 1340         |            | 0.467     | 0.463      | 2.80            | 0.110      | 2.70             | 0.125      | 2.60             | 0.139      | 2.50             | 0.163      |
|           |            | T = 2100         |            |                  |            | 0.499     | 0.460      | 2.90            | 0.104      | 2.80             | 0.118      | 2.70             | 0.132      | 2.60             | 0.156      |
| 0.40      | 0.470      | 1.120            | 0.386      | 0.548            | 0.453      | 3.00      | 0.099      | 2.90            | 0.112      | 2.80             | 0.125      | 2.70             | 0.150      | 2.60             | 0.169      |
| 0.50      | 0.451      | 1.449            | 0.295      | 0.578            | 0.449      | 3.20      | 0.089      | 3.00            | 0.106      | 2.90             | 0.119      | 2.80             | 0.143      | 2.70             | 0.163      |
| 0.70      | 0.420      | 2.002            | 0.223      | 0.698            | 0.431      | 3.40      | 0.082      | 3.20            | 0.097      | 3.00             | 0.114      | 2.90             | 0.137      | 2.80             | 0.157      |
| 1.00      | 0.390      | 2.204            | 0.208      |                  |            | 3.80      | 0.068      | 3.60            | 0.082      | 3.40             | 0.096      | 3.20             | 0.122      | 3.00             | 0.146      |
|           |            |                  |            |                  |            |           |            |                 |            |                  |            |                  |            | 3.20             | 0.136      |

<sup>a</sup> Not shown on plot

DATA TABLE NO. 252 (continued)

| $\lambda$                            | $\epsilon$ | $\lambda$                    | $\epsilon$ | $\lambda$                    | $\epsilon$ | $\lambda$                            | $\epsilon$ | $\lambda$ | $\epsilon$ |
|--------------------------------------|------------|--------------------------------------|------------|--------------------------------------|------------|--------------------------------------|------------|--------------------------------------|------------|------------------------------|------------|------------------------------|------------|--------------------------------------|------------|-----------|------------|
| CURVE 80 (cont.)*<br><u>T = 1833</u> |            | CURVE 81 (cont.)*<br><u>T = 2002</u> |            | CURVE 82 (cont.)*<br><u>T = 2160</u> |            | CURVE 83 (cont.)*<br><u>T = 2327</u> |            | CURVE 84 (cont.)*<br><u>T = 2441</u> |            | CURVE 87*<br><u>T = 1500</u> |            | CURVE 90*<br><u>T = 2143</u> |            | CURVE 92 (cont.)*<br><u>T = 1800</u> |            |           |            |
| 3.40                                 | 0.128      | 3.20                                 | 0.147      | 3.00                                 | 0.167      | 2.90                                 | 0.179      | 2.80                                 | 0.191      | 0.46                         | 0.529      | 0.3478                       | 0.485      | 0.365                                | 0.477      |           |            |
| 3.60                                 | 0.121      | 3.40                                 | 0.139      | 3.20                                 | 0.157      | 3.00                                 | 0.174      | 2.90                                 | 0.186      | 0.49                         | 0.519      | 0.3717                       | 0.495      | 0.383                                | 0.478      |           |            |
| 3.80                                 | 0.114      | 3.60                                 | 0.132      | 3.40                                 | 0.149      | 3.20                                 | 0.166      | 3.00                                 | 0.181      | 0.55                         | 0.507      | 0.3956                       | 0.493      | 0.450                                | 0.470      |           |            |
| 4.00                                 | 0.108      | 3.80                                 | 0.125      | 3.60                                 | 0.142      | 3.40                                 | 0.157      | 3.20                                 | 0.172      | 0.61                         | 0.494      | 0.4196                       | 0.503      | 0.545                                | 0.461      |           |            |
| 4.20                                 | 0.102      | 4.00                                 | 0.119      | 3.80                                 | 0.135      | 3.60                                 | 0.151      | 3.40                                 | 0.164      | 0.79                         | 0.450      | 0.4435                       | 0.470      | 0.612                                | 0.450      |           |            |
| 4.40                                 | 0.097      | 4.20                                 | 0.113      | 4.00                                 | 0.129      | 3.80                                 | 0.144      | 3.60                                 | 0.158      | 1.00                         | 0.405      | 0.4677                       | 0.475      | 0.731                                | 0.437      |           |            |
| 4.60                                 | 0.092      | 4.40                                 | 0.108      | 4.20                                 | 0.124      | 4.00                                 | 0.139      | 3.80                                 | 0.151      | 1.19                         | 0.357      | 0.4916                       | 0.463      | 0.828                                | 0.423      |           |            |
| 4.80                                 | 0.088      | 4.60                                 | 0.103      | 4.40                                 | 0.119      | 4.20                                 | 0.134      | 4.00                                 | 0.146      | 1.40                         | 0.315      | 0.5158                       | 0.453      | 0.972                                | 0.393      |           |            |
| 5.00                                 | 0.084      | 4.80                                 | 0.099      | 4.60                                 | 0.114      | 4.40                                 | 0.128      | 4.20                                 | 0.140      | 1.61                         | 0.268      | 0.5400                       | 0.438      | 1.10                                 | 0.363      |           |            |
| 5.10                                 | 0.082      | 5.00                                 | 0.095      | 4.80                                 | 0.110      | 4.60                                 | 0.124      | 4.40                                 | 0.136      | 1.79                         | 0.240      | 0.5641                       | 0.415      | 1.27                                 | 0.329      |           |            |
|                                      |            | 5.10                                 | 0.093      | 5.00                                 | 0.106      | 4.80                                 | 0.120      | 4.60                                 | 0.132      | 2.00                         | 0.208      |                              |            | 1.48                                 | 0.289      |           |            |
| CURVE 81*<br><u>T = 2002</u>         |            | CURVE 82*<br><u>T = 2160</u>         |            | CURVE 83*<br><u>T = 2327</u>         |            | CURVE 84*<br><u>T = 2441</u>         |            | CURVE 85<br><u>T = 300</u>           |            | CURVE 87*<br><u>T = 1500</u> |            | CURVE 90*<br><u>T = 2143</u> |            | CURVE 92 (cont.)*<br><u>T = 1800</u> |            |           |            |
| 1.00                                 | 0.378      | 1.00                                 | 0.374      | 1.00                                 | 0.371      | 1.00                                 | 0.369      | 1.05                                 | 0.362      | 0.46                         | 0.506      | 0.230                        | 0.393      | 2.70                                 | 0.170      |           |            |
| 1.05                                 | 0.369      | 1.05                                 | 0.366      | 1.05                                 | 0.364      | 1.05                                 | 0.369      | 1.10                                 | 0.354      | 0.49                         | 0.503      | 0.244                        | 0.438      |                                      |            |           |            |
| 1.10                                 | 0.359      | 1.05                                 | 0.366      | 1.05                                 | 0.364      | 1.05                                 | 0.369      | 1.15                                 | 0.347      | 0.55                         | 0.507      | 0.264                        | 0.469      | CURVE 93*<br><u>T = 2000</u>         |            |           |            |
| 1.15                                 | 0.351      | 1.10                                 | 0.357      | 1.05                                 | 0.364      | 1.10                                 | 0.356      | 1.15                                 | 0.348      | 0.55                         | 0.537      | 0.280                        | 0.478      |                                      |            |           |            |
| 1.20                                 | 0.341      | 1.15                                 | 0.349      | 1.10                                 | 0.356      | 1.10                                 | 0.362      | 1.20                                 | 0.339      | 0.61                         | 0.519      | 0.299                        | 0.481      |                                      |            |           |            |
| 1.24                                 | 0.333      | 1.20                                 | 0.341      | 1.15                                 | 0.348      | 1.15                                 | 0.354      | 1.25                                 | 0.347      | 0.61                         | 0.519      | 0.335                        | 0.477      | 0.229                                | 0.374      |           |            |
| 1.30                                 | 0.323      | 1.24                                 | 0.333      | 1.20                                 | 0.340      | 1.20                                 | 0.340      | 1.30                                 | 0.347      | 0.55                         | 0.537      | 0.398                        | 0.479      | 0.240                                | 0.415      |           |            |
| 1.35                                 | 0.314      | 1.30                                 | 0.324      | 1.24                                 | 0.333      | 1.24                                 | 0.333      | 1.35                                 | 0.347      | 0.59                         | 0.557      | 0.360                        | 0.481      | 0.259                                | 0.451      |           |            |
| 1.40                                 | 0.306      | 1.35                                 | 0.316      | 1.30                                 | 0.324      | 1.30                                 | 0.333      | 1.40                                 | 0.347      | 0.61                         | 0.560      | 0.312                        | 0.473      | 0.279                                | 0.468      |           |            |
| 1.45                                 | 0.298      | 1.40                                 | 0.308      | 1.35                                 | 0.317      | 1.35                                 | 0.325      | 1.45                                 | 0.347      | 0.61                         | 0.562      | 0.312                        | 0.473      | 0.302                                | 0.473      |           |            |
| 1.50                                 | 0.291      | 1.45                                 | 0.301      | 1.40                                 | 0.310      | 1.40                                 | 0.318      | 1.50                                 | 0.347      | 0.61                         | 0.562      | 0.323                        | 0.471      | 0.323                                | 0.471      |           |            |
| 1.55                                 | 0.284      | 1.50                                 | 0.294      | 1.45                                 | 0.303      | 1.45                                 | 0.312      | 1.55                                 | 0.347      | 0.61                         | 0.562      | 0.325                        | 0.471      | 0.343                                | 0.471      |           |            |
| 1.60                                 | 0.277      | 1.55                                 | 0.287      | 1.50                                 | 0.297      | 1.50                                 | 0.305      | 1.60                                 | 0.347      | 0.61                         | 0.562      | 0.322                        | 0.471      | 0.380                                | 0.475      |           |            |
| 1.65                                 | 0.271      | 1.60                                 | 0.280      | 1.55                                 | 0.291      | 1.55                                 | 0.299      | 1.65                                 | 0.347      | 0.61                         | 0.562      | 0.322                        | 0.471      | 0.380                                | 0.475      |           |            |
| 1.70                                 | 0.264      | 1.65                                 | 0.274      | 1.60                                 | 0.285      | 1.60                                 | 0.294      | 1.70                                 | 0.347      | 0.61                         | 0.562      | 0.322                        | 0.471      | 0.380                                | 0.475      |           |            |
| 1.75                                 | 0.257      | 1.70                                 | 0.268      | 1.65                                 | 0.279      | 1.65                                 | 0.288      | 1.80                                 | 0.347      | 0.61                         | 0.562      | 0.322                        | 0.471      | 0.380                                | 0.475      |           |            |
| 1.80                                 | 0.251      | 1.75                                 | 0.262      | 1.70                                 | 0.273      | 1.65                                 | 0.282      | 1.85                                 | 0.347      | 0.61                         | 0.562      | 0.322                        | 0.471      | 0.380                                | 0.475      |           |            |
| 1.85                                 | 0.245      | 1.80                                 | 0.251      | 1.75                                 | 0.268      | 1.70                                 | 0.277      | 1.90                                 | 0.347      | 0.61                         | 0.562      | 0.322                        | 0.471      | 0.380                                | 0.475      |           |            |
| 1.90                                 | 0.239      | 1.85                                 | 0.251      | 1.80                                 | 0.262      | 1.75                                 | 0.272      | 1.95                                 | 0.347      | 0.61                         | 0.562      | 0.322                        | 0.471      | 0.380                                | 0.475      |           |            |
| 1.95                                 | 0.234      | 1.90                                 | 0.245      | 1.85                                 | 0.257      | 1.80                                 | 0.266      | 2.00                                 | 0.347      | 0.61                         | 0.562      | 0.322                        | 0.471      | 0.380                                | 0.475      |           |            |
| 2.00                                 | 0.229      | 1.95                                 | 0.241      | 1.90                                 | 0.252      | 1.85                                 | 0.262      | 2.05                                 | 0.347      | 0.61                         | 0.562      | 0.322                        | 0.471      | 0.380                                | 0.475      |           |            |
| 2.10                                 | 0.220      | 2.00                                 | 0.236      | 1.95                                 | 0.247      | 1.90                                 | 0.257      | 2.10                                 | 0.347      | 0.61                         | 0.562      | 0.322                        | 0.471      | 0.380                                | 0.475      |           |            |
| 2.20                                 | 0.211      | 2.10                                 | 0.227      | 2.00                                 | 0.243      | 1.95                                 | 0.252      | 2.15                                 | 0.347      | 0.61                         | 0.562      | 0.322                        | 0.471      | 0.380                                | 0.475      |           |            |
| 2.30                                 | 0.202      | 2.20                                 | 0.218      | 2.10                                 | 0.234      | 2.00                                 | 0.248      | 2.20                                 | 0.347      | 0.61                         | 0.562      | 0.322                        | 0.471      | 0.380                                | 0.475      |           |            |
| 2.40                                 | 0.194      | 2.30                                 | 0.210      | 2.20                                 | 0.225      | 2.10                                 | 0.239      | 2.25                                 | 0.347      | 0.61                         | 0.562      | 0.322                        | 0.471      | 0.380                                | 0.475      |           |            |
| 2.50                                 | 0.187      | 2.40                                 | 0.202      | 2.30                                 | 0.217      | 2.20                                 | 0.231      | 2.30                                 | 0.347      | 0.61                         | 0.562      | 0.322                        | 0.471      | 0.380                                | 0.475      |           |            |
| 2.60                                 | 0.180      | 2.50                                 | 0.195      | 2.40                                 | 0.209      | 2.30                                 | 0.223      | 2.40                                 | 0.347      | 0.61                         | 0.562      | 0.322                        | 0.471      | 0.380                                | 0.475      |           |            |
| 2.70                                 | 0.173      | 2.60                                 | 0.189      | 2.50                                 | 0.202      | 2.40                                 | 0.216      | 2.50                                 | 0.347      | 0.61                         | 0.562      | 0.322                        | 0.471      | 0.380                                | 0.475      |           |            |
| 2.80                                 | 0.167      | 2.70                                 | 0.183      | 2.60                                 | 0.195      | 2.50                                 | 0.209      | 2.60                                 | 0.347      | 0.61                         | 0.562      | 0.322                        | 0.471      | 0.380                                | 0.475      |           |            |
| 2.90                                 | 0.162      | 2.80                                 | 0.177      | 2.70                                 | 0.189      | 2.60                                 | 0.202      | 2.70                                 | 0.347      | 0.61                         | 0.562      | 0.322                        | 0.471      | 0.380                                | 0.475      |           |            |
| 3.00                                 | 0.157      | 2.90                                 | 0.172      | 2.80                                 | 0.184      | 2.70                                 | 0.196      |                                      |            |                              |            | 0.327                        | 0.474      |                                      |            |           |            |

\* Not shown on plot

DATA TABLE NO. 252 (continued)

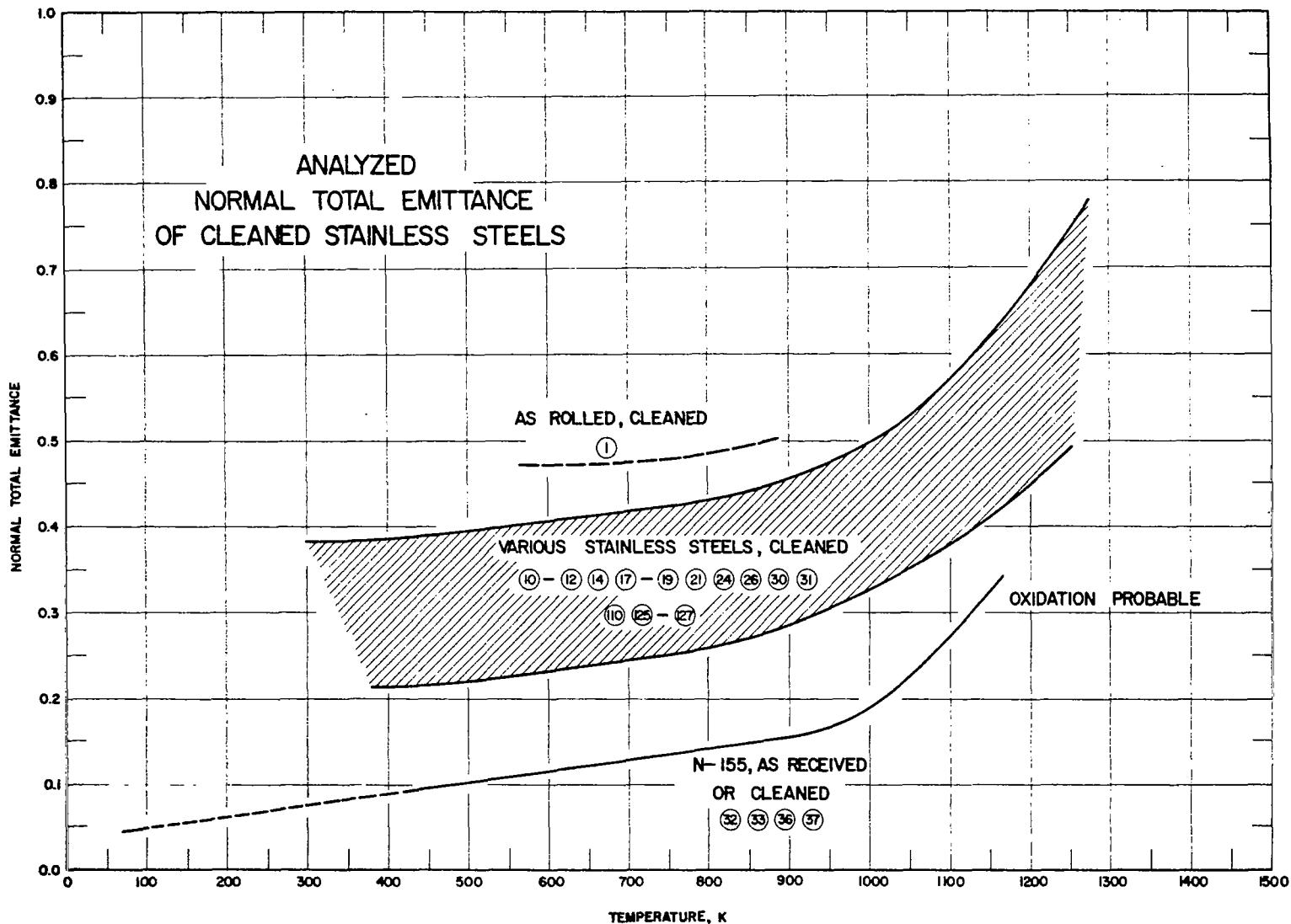
| λ                | ε | λ                | ε |
|------------------|---|------------------|---|
| <u>CURVE 94*</u> |   | <u>CURVE 96*</u> |   |
| <u>T = 2200</u>  |   | <u>T = 2600</u>  |   |

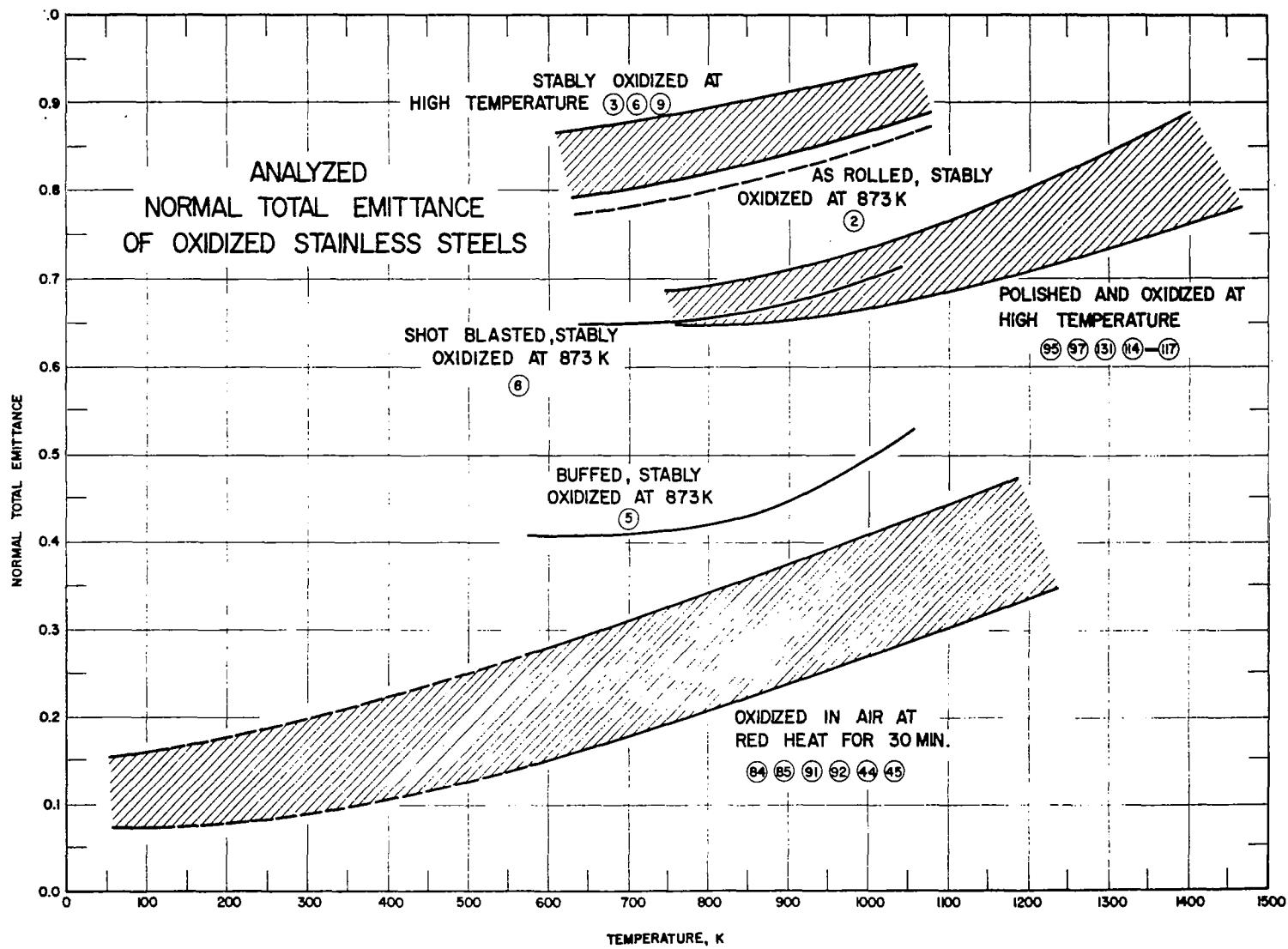
|       |       |       |       |
|-------|-------|-------|-------|
| 0.231 | 0.364 | 0.231 | 0.363 |
| 0.247 | 0.427 | 0.241 | 0.400 |
| 0.264 | 0.452 | 0.260 | 0.437 |
| 0.285 | 0.466 | 0.283 | 0.454 |
| 0.306 | 0.469 | 0.301 | 0.460 |
| 0.331 | 0.467 | 0.340 | 0.462 |
| 0.375 | 0.471 | 0.377 | 0.465 |
| 0.451 | 0.463 | 0.419 | 0.460 |
| 0.553 | 0.452 | 0.502 | 0.450 |
| 0.604 | 0.444 | 0.567 | 0.443 |
| 0.704 | 0.432 | 0.654 | 0.430 |
| 0.807 | 0.414 | 0.756 | 0.413 |
| 0.918 | 0.392 | 0.883 | 0.390 |
| 1.27  | 0.329 | 1.04  | 0.364 |
| 1.60  | 0.279 | 1.27  | 0.328 |
| 2.00  | 0.236 | 1.60  | 0.289 |
| 2.40  | 0.206 | 2.00  | 0.250 |
| 2.68  | 0.191 | 2.41  | 0.224 |
|       |       | 2.69  | 0.210 |

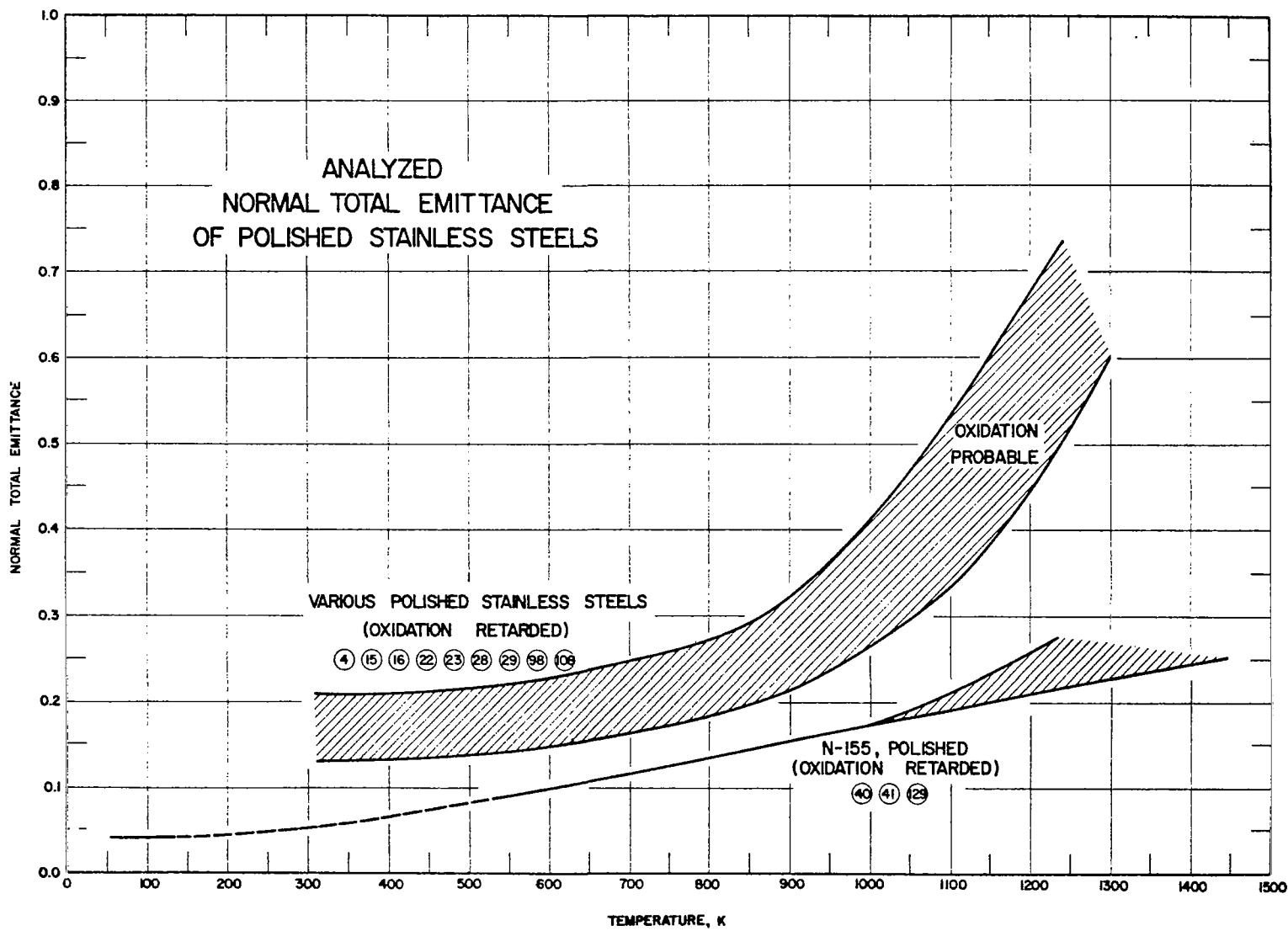
|                  |  |                  |  |
|------------------|--|------------------|--|
| <u>CURVE 95*</u> |  | <u>CURVE 97*</u> |  |
| <u>T = 2400</u>  |  | <u>T = 2800</u>  |  |

|       |       |       |       |
|-------|-------|-------|-------|
| 0.231 | 0.363 | 0.229 | 0.350 |
| 0.238 | 0.397 | 0.238 | 0.386 |
| 0.247 | 0.419 | 0.248 | 0.412 |
| 0.258 | 0.439 | 0.268 | 0.440 |
| 0.273 | 0.455 | 0.293 | 0.455 |
| 0.293 | 0.463 | 0.332 | 0.457 |
| 0.314 | 0.465 | 0.364 | 0.462 |
| 0.331 | 0.464 | 0.384 | 0.462 |
| 0.373 | 0.469 | 0.450 | 0.453 |
| 0.400 | 0.466 | 0.554 | 0.443 |
| 0.451 | 0.459 | 0.604 | 0.433 |
| 0.526 | 0.452 | 0.704 | 0.420 |
| 0.562 | 0.448 | 0.822 | 0.397 |
| 0.608 | 0.440 | 0.979 | 0.371 |
| 0.706 | 0.428 | 1.11  | 0.350 |
| 0.820 | 0.407 | 1.27  | 0.328 |
| 0.942 | 0.384 | 1.51  | 0.302 |
| 1.14  | 0.350 | 1.85  | 0.270 |
| 1.27  | 0.329 | 2.21  | 0.245 |
| 1.55  | 0.290 | 2.68  | 0.220 |
| 1.83  | 0.259 |       |       |
| 2.21  | 0.228 |       |       |
| 2.68  | 0.201 |       |       |

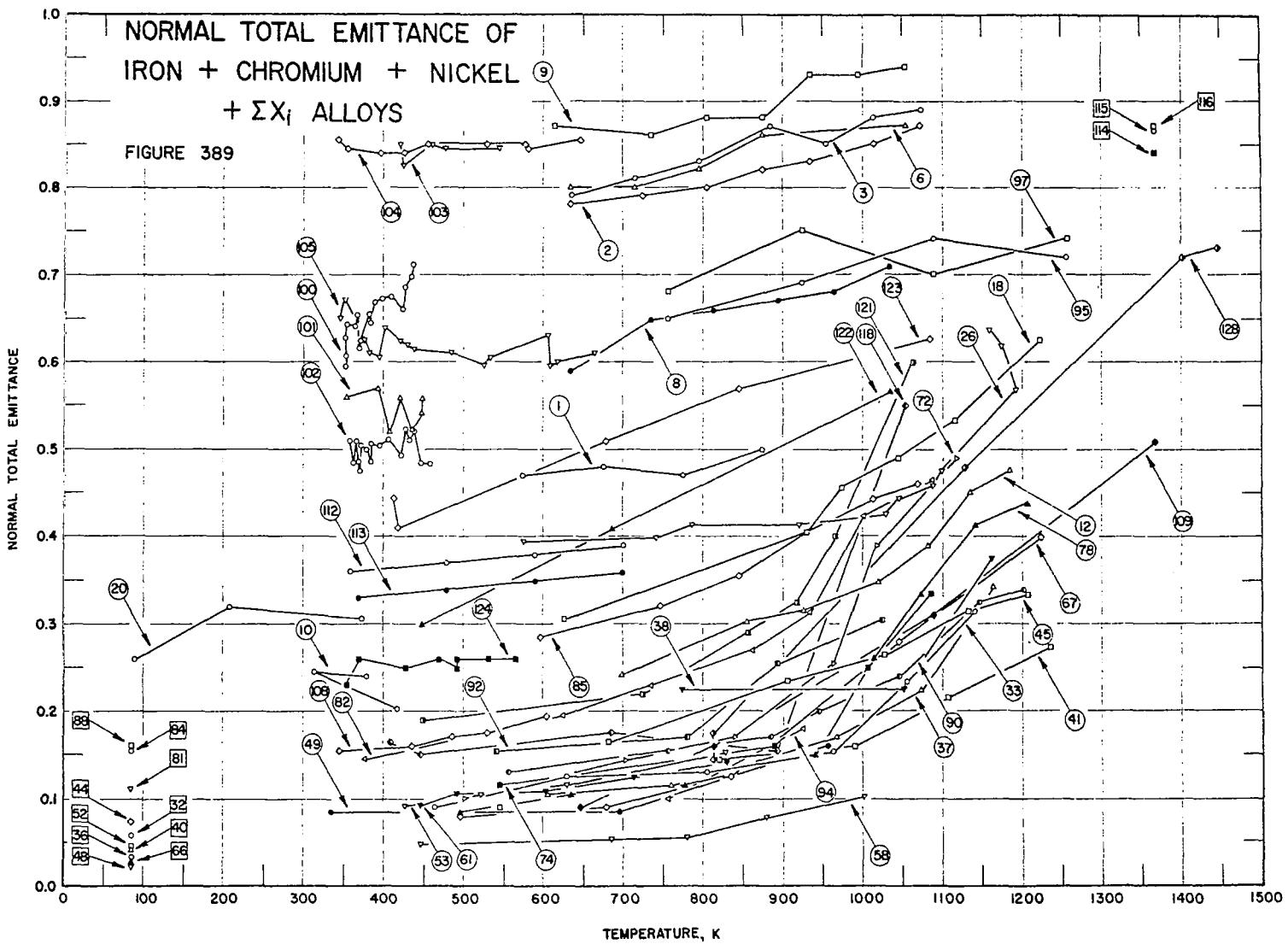
\* Not shown on plot







L7



SPECIFICATION TABLE NO. 389 NORMAL TOTAL EMITTANCE OF [IRON + CHROMIUM + NICKEL +  $\Sigma X_i$ ] ALLOYS

| Curve No. | Ref. No. | Year | Temperature Range, K | Geometry $\theta^{\circ}$ | Reported Error, % | Composition (weight percent), Specifications and Remarks   |
|-----------|----------|------|----------------------|---------------------------|-------------------|--|
| 1         | 68       | 1952 | 573-873              | $\sim 0^{\circ}$          |                   | Stainless steel Vickers F.D.P.; nominal composition: 18 Cr, 8 Ni, Fe balance; as rolled; cleaned with $CCl_4$ ; measured in air.   |
| 2         | 68       | 1952 | 633-1073             | $\sim 0^{\circ}$          |                   | Different sample, same as curve 1 specimen and conditions; oxidized at 873 K until steady state reached.   |
| 3         | 68       | 1952 | 633-1073             | $\sim 0^{\circ}$          |                   | Different sample, same as curve 1 specimen and conditions except oxidized at 1173 K until steady state reached.  |
| 4         | 68       | 1952 | 663-893              | $\sim 0^{\circ}$          |                   | Different sample, same as curve 1 specimen and conditions except buffed.   |
| 5         | 68       | 1952 | 573-1053             | $\sim 0^{\circ}$          |                   | Different sample, same as curve 4 specimen and conditions; oxidized at 873 K until steady state reached.   |
| 6         | 68       | 1952 | 633-1053             | $\sim 0^{\circ}$          |                   | Different sample, same as curve 4 specimen and conditions except oxidized at 1173 K until steady state reached.  |
| 7         | 68       | 1952 | 583-873              | $\sim 0^{\circ}$          |                   | Different sample, same as curve 1 specimen and conditions except shot blasted with fused alumina.  |
| 8         | 68       | 1952 | 633-1033             | $\sim 0^{\circ}$          |                   | Different sample, same as curve 7 specimen and conditions; oxidized at 873 K until steady state reached.   |
| 9         | 68       | 1952 | 613-1053             | $\sim 0^{\circ}$          |                   | Different sample, same as curve 7 specimen and conditions except oxidized at 1173 K until steady state reached.  |
| 10        | 160      | 1954 | 377-414              | $\sim 0^{\circ}$          |                   | Stainless steel 301; nominal composition: 16.00-18.00 Cr, 6.00-8.00 Ni, 2.00 max Mn, 1.00 max Si, 0.15 max C, Fe balance; cleaned with methyl alcohol; measured in vacuum ( $10^{-3}$ mm Hg); [Author's designation: Sample 6].              |
| 11        | 160      | 1954 | 505-1280             | $\sim 0^{\circ}$          |                   | Different sample, same as above specimen and conditions except measured in argon ( $10^{-3}$ mm Hg); [Author's designation: Sample 11].  |
| 12        | 160      | 1954 | 697-1183             | $\sim 0^{\circ}$          |                   | Above specimen and conditions.   |
| 13        | 160      | 1954 | 88.9-364             | $\sim 0^{\circ}$          |                   | Different sample, same as curve 10 specimen and conditions except scrubbed with Bon Ami on a wet cloth, washed and dried, wiped with toluene and alcohol; [Author's designation: Sample 2].  |
| 14        | 160      | 1954 | 439-1347             | $\sim 0^{\circ}$          |                   | Different sample, same as above specimen and conditions except measured in argon ( $10^{-3}$ mm Hg); heating and cooling; [Author's designation: Sample 12].   |
| 15        | 160      | 1954 | 305-412              | $\sim 0^{\circ}$          |                   | Different sample, same as curve 10 specimen and conditions except polished, then finished with a wool buff and rouge and washed; surface free from scratches; [Author's designation: Sample 4].  |
| 16        | 160      | 1954 | 469-1258             | $\sim 0^{\circ}$          |                   | Different sample, same as above specimen and conditions except measured in argon ( $10^{-3}$ mm Hg); [Author's designation: Sample 13].  |
| 17        | 160      | 1954 | 310-423              | $\sim 0^{\circ}$          |                   | Stainless steel 316; nominal composition: 16.00-18.00 Cr, 10.00-14.00 Ni, 2.00-3.00 Mo, 2.00 max Mn, 1.00 max Si, 0.08 max C; cleaned with methyl alcohol; measured in vacuum ( $10^{-3}$ mm Hg); heating; [Author's designation: Sample 1]. |

SPECIFICATION TABLE NO. 389 (continued)

| Curve No. | Ref. No. | Year | Temperature Range, K | Geometry $\theta'$ | Reported Error, % | Composition (weight percent), Specifications and Remarks  |
|-----------|----------|------|----------------------|--------------------|-------------------|---|
| 18        | 160      | 1954 | 623-1221             | $\sim 0^\circ$     |                   | Different sample, same as above specimen and conditions except measured in argon ( $10^{-3}$ mm Hg); [Author's designation: Sample 10].   |
| 19        | 160      | 1954 | 496-1219             | $\sim 0^\circ$     |                   | Above specimen and conditions.  |
| 20        | 160      | 1954 | 88, 9-372            | $\sim 0^\circ$     |                   | Different sample, same as curve 17 specimen and conditions except scrubbed with Bon Ami on a wet cloth, washed and dried, wiped with toluene and alcohol; [Author's designation: Sample 2].   |
| 21        | 160      | 1954 | 517-1402             | $\sim 0^\circ$     |                   | Different sample, same as above specimen and conditions except measured in argon ( $10^{-3}$ mm Hg); [Author's designation: Sample 11].   |
| 22        | 160      | 1954 | 314-432              | $\sim 0^\circ$     |                   | Different sample, same as curve 17 specimen and conditions except polished and then finished with a wool buff and rouge and washed; surface free from scratches; [Author's designation: Sample 3].  |
| 23        | 160      | 1954 | 281-1417             | $\sim 0^\circ$     |                   | Different sample, same as above specimen and conditions except measured in argon ( $10^{-3}$ mm Hg); [Author's designation: Sample 12].   |
| 24        | 160      | 1954 | 318-423              | $\sim 0^\circ$     |                   | Stainless steel 347; nominal composition: 17.00-19.00 Cr, 9.00-13.00 Ni, 2.00 max Mn, 1.00 max Si, 0.08 max C, 10 x C min Nb-Ta, Fe balance; cleaned with methyl alcohol; measured in vacuum ( $10^{-3}$ mm Hg); heating; [Author's designation: Sample 7]. |
| 25        | 160      | 1954 | 319-423              | $\sim 0^\circ$     |                   | Different sample, same as curve 24 specimen and conditions; [Author's designation: Sample 13].  |
| 26        | 160      | 1954 | 574-1191             | $\sim 0^\circ$     |                   | Different sample, same as curve 24 specimen and conditions except measured in argon ( $10^{-3}$ mm Hg); [Author's designation: Sample 12].  |
| 27        | 160      | 1954 | 474-1192             | $\sim 0^\circ$     |                   | Above specimen and conditions except heating and cooling.   |
| 28        | 160      | 1954 | 303-426              | $\sim 0^\circ$     |                   | Different sample, same as curve 24 specimen and conditions except polished and then finished with a wool buff and rouge and washed; surface free from scratches; [Author's designation: Sample 6].  |
| 29        | 160      | 1954 | 488-1294             | $\sim 0^\circ$     |                   | Different sample, same as curve 28 specimen and conditions except measured in argon ( $10^{-3}$ mm Hg); [Author's designation: Sample 15].  |
| 30        | 160      | 1954 | 303-434              | $\sim 0^\circ$     |                   | Different sample, same as curve 24 specimen and conditions except scrubbed with Bon Ami on a wet cloth, washed and dried, wiped with toluene and alcohol; [Author's designation: Sample 5].   |
| 31        | 160      | 1954 | 493-1267             | $\sim 0^\circ$     |                   | Different sample, same as curve 30 specimen and conditions except measured in argon ( $10^{-3}$ mm Hg); [Author's designation: Sample 14].  |
| 32        | 34       | 1957 | 83.2                 | $\sim 0^\circ$     | $\pm 10$          | Cobalt alloy N-155; nominal composition: 21 Cr, 20 Co, 20 Ni, 3 Mo, 3 W, 1.5 Mn, 1 Nb, 0.5 Si, 0.15 C, 0.15 N, Fe balance; as received; measured in vacuum ( $5 \times 10^{-4}$ mm Hg).   |
| 33        | 34       | 1957 | 461-1139             | $\sim 0^\circ$     | $\pm 10$          | Different sample, same as above specimen and conditions; increasing temp, cycle 1.  |
| 34        | 34       | 1957 | 533-850              | $\sim 0^\circ$     | $\pm 10$          | Above specimen and conditions; cycle 2.   |

SPECIFICATION TABLE NO. 389 (continued)

| Curve No. | Ref. No. | Year | Temperature Range, K | Geometry $\theta'$ | Reported Error, % | Composition (weight percent), Specifications and Remarks   |
|-----------|----------|------|----------------------|--------------------|-------------------|--|
| 35        | 34       | 1957 | 522                  | $\sim 0^\circ$     | $\pm 10$          | Above specimen and conditions; cycle 3.  |
| 36        | 34       | 1957 | 83.2                 | $\sim 0^\circ$     | $\pm 10$          | Different sample, same as curve 32 specimen and conditions except cleaned with liquid detergent.   |
| 37        | 34       | 1957 | 603-1161             | $\sim 0^\circ$     | $\bullet 10$      | Different sample, same as above specimen and conditions; increasing temp, cycle 1.   |
| 38        | 34       | 1957 | 772-1161             | $\sim 0^\circ$     | $\bullet 10$      | Above specimen and conditions; cycle 2.  |
| 39        | 34       | 1957 | 800-1003             | $\sim 0^\circ$     | $\pm 10$          | Above specimen and conditions; cycle 3.  |
| 40        | 34       | 1957 | 83.2                 | $\sim 0^\circ$     | $\pm 10$          | Different sample, same as curve 32 specimen and conditions except polished.  |
| 41        | 34       | 1957 | 544-1233             | $\sim 0^\circ$     | $\pm 10$          | Different sample, same as above specimen and conditions; increasing temp, cycle 1.   |
| 42        | 34       | 1957 | 811-989              | $\sim 0^\circ$     | $\pm 10$          | Above specimen and conditions; cycle 2.  |
| 43        | 34       | 1957 | 911-1108             | $\sim 0^\circ$     | $\bullet 10$      | Above specimen and conditions; cycle 3.  |
| 44        | 34       | 1957 | 83.2                 | $\sim 0^\circ$     | $\pm 10$          | Different sample, same as curve 32 specimen and conditions except oxidized in air at red heat for 30 min.  |
| 45        | 34       | 1957 | 680-1205             | $\sim 0^\circ$     | $\bullet 10$      | Different sample, same as above specimen and conditions; increasing temp, cycle 1.   |
| 46        | 34       | 1957 | 769-911              | $\sim 0^\circ$     | $\pm 10$          | Above specimen and conditions; cycle 2.  |
| 47        | 34       | 1957 | 611-1289             | $\sim 0^\circ$     | $\pm 10$          | Above specimen and conditions; cycle 3.  |
| 48        | 34       | 1957 | 83.2                 | $\sim 0^\circ$     | $\bullet 10$      | Stainless steel type PH 15-7 Mo; nominal composition: 15 Cr, 7 Ni, 2.25 Mo, 1.15 Al, 0.70 Mn, 0.40 Si, 0.07 C, Fe balance; surface roughness ~2 microinches rms; measured in vacuum ( $5 \times 10^{-4}$ mm Hg). |
| 49        | 34       | 1957 | 333-955              | $\sim 0^\circ$     | $\pm 10$          | Different sample, same as above specimen and conditions; increasing temp, cycle 1.   |
| 50        | 34       | 1957 | 661-866              | $\sim 0^\circ$     | $\pm 10$          | Above specimen and conditions; cycle 2.  |
| 51        | 34       | 1957 | 511-950              | $\sim 0^\circ$     | $\bullet 10$      | Above specimen and conditions; cycle 3.  |
| 52        | 34       | 1957 | 83.2                 | $\sim 0^\circ$     | $\pm 10$          | Different sample, same as curve 48 specimen and conditions; surface roughness ~15 microinches.   |
| 53        | 34       | 1957 | 425-828              | $\sim 0^\circ$     | $\pm 10$          | Different sample, same as above specimen and conditions; increasing temp, cycle 1.   |
| 54        | 34       | 1957 | 483-878              | $\sim 0^\circ$     | $\pm 10$          | Above specimen and conditions; cycle 2.  |
| 55        | 34       | 1957 | 625-844              | $\sim 0^\circ$     | $\pm 10$          | Above specimen and conditions; cycle 3.  |
| 56        | 34       | 1957 | 83.2                 | $\sim 0^\circ$     | $\pm 10$          | Stainless steel type 17-7 PH; nominal composition: 17 Cr, 7 Ni, 1.15 Al, 0.70 Mn, 0.40 Si, 0.07 C, Fe balance; surface roughness ~2 microinches rms; measured in vacuum ( $5 \times 10^{-4}$ mm Hg).             |
| 57        | 34       | 1957 | 472-755              | $\sim 0^\circ$     | $\pm 10$          | Different sample, same as above specimen and conditions except increasing temp, cycle 1.   |
| 58        | 34       | 1957 | 444-1000             | $\sim 0^\circ$     | $\bullet 10$      | Above specimen and conditions; cycle 2.  |
| 59        | 34       | 1957 | 650-933              | $\sim 0^\circ$     | $\pm 10$          | Above specimen and conditions; cycle 3.  |

## SPECIFICATION TABLE NO. 389 (continued)

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| Curve No. | Ref. No. | Year | Temperature Range, K | Geometry $\theta^{\circ}$ | Reported Error, % | Composition (weight percent), Specifications and Remarks  |
|-----------|----------|------|----------------------|---------------------------|-------------------|---|
| 60        | 34       | 1957 | 83.2                 | $\sim 0^{\circ}$          | $\pm 10$          | Different sample, same as curve 56 specimen and conditions; surface roughness $\sim 15$ microinches rms.  |
| 61        | 34       | 1957 | 444-828              | $\sim 0^{\circ}$          | $\pm 10$          | Different sample, same as above specimen and conditions except increasing temp., cycle 1.   |
| 62        | 34       | 1957 | 661-1053             | $\sim 0^{\circ}$          | $\pm 10$          | Above specimen and conditions; cycle 2.   |
| 63        | 34       | 1957 | 605                  | $\sim 0^{\circ}$          | $\pm 10$          | Above specimen and conditions; decreasing temp., cycle 2.   |
| 64        | 34       | 1957 | 478-722              | $\sim 0^{\circ}$          | $\pm 10$          | Above specimen and conditions; cycle 3.   |
| 65        | 34       | 1957 | 616                  | $\sim 0^{\circ}$          | $\pm 10$          | Above specimen and conditions; decreasing temp., cycle 3.   |
| 66        | 34       | 1957 | 83.2                 | $\sim 0^{\circ}$          | $\pm 10$          | Stainless steel type 316; nominal composition: 16.00-18.00 Cr, 10.00-14.00 Ni, 2.00-3.00 Mo, 2.00 max Mn, 1.00 max Si, 0.08 max C, Fe balance; surface roughness $\sim 2$ micro-inches rms; measured in vacuum ( $5 \times 10^{-4}$ mm Hg). |
| 67        | 34       | 1957 | 494-1222             | $\sim 0^{\circ}$          | $\pm 10$          | Different sample, same as above specimen and conditions except increasing temp., cycle 1.   |
| 68        | 34       | 1957 | 505-1039             | $\sim 0^{\circ}$          | $\pm 10$          | Above specimen and conditions; cycle 2.   |
| 69        | 34       | 1957 | 83.2                 | $\sim 0^{\circ}$          | $\pm 10$          | Different sample, same as curve 66 specimen and conditions; surface roughness $\sim 15$ micro-inches rms.   |
| 70        | 34       | 1957 | 444-628              | $\sim 0^{\circ}$          | $\pm 10$          | Different sample, same as above specimen and conditions except increasing temp., cycle 1.   |
| 71        | 34       | 1957 | 466-855              | $\sim 0^{\circ}$          | $\pm 10$          | Above specimen and conditions; cycle 2.   |
| 72        | 34       | 1957 | 500-1116             | $\sim 0^{\circ}$          | $\pm 10$          | Above specimen and conditions; cycle 3.   |
| 73        | 34       | 1957 | 83.2                 | $\sim 0^{\circ}$          | $\pm 10$          | Stainless steel type 321; nominal composition: 17.00-19.00 Cr, 9.00-12.00 Ni, 2.00 max Mn, 1.00 max Si, 0.08 max C, 5 $\times$ C min Ti, Fe balance; bright finish; measured in vacuum ( $5 \times 10^{-4}$ mm Hg).                         |
| 74        | 34       | 1957 | 544-1083             | $\sim 0^{\circ}$          | $\pm 10$          | Different sample, same as above specimen and conditions except increasing temp., cycle 1.   |
| 75        | 34       | 1957 | 622-894              | $\sim 0^{\circ}$          | $\pm 10$          | Above specimen and conditions; cycle 2.   |
| 76        | 34       | 1957 | 872-1122             | $\sim 0^{\circ}$          | $\pm 10$          | Above specimen and conditions; cycle 3.   |
| 77        | 34       | 1957 | 83.2                 | $\sim 0^{\circ}$          | $\pm 10$          | Different sample, same as curve 73 specimen and conditions; surface roughness $\sim 2$ micro-inches rms.  |
| 78        | 34       | 1957 | 494-1205             | $\sim 0^{\circ}$          | $\pm 10$          | Different sample, same as above specimen and conditions except increasing temp., cycle 1.   |
| 79        | 34       | 1957 | 633-994              | $\sim 0^{\circ}$          | $\pm 10$          | Above specimen and conditions; cycle 2.   |
| 80        | 34       | 1957 | 728-1061             | $\sim 0^{\circ}$          | $\pm 10$          | Above specimen and conditions; cycle 3.   |
| 81        | 34       | 1957 | 83.2                 | $\sim 0^{\circ}$          | $\pm 10$          | Different sample, same as curve 73 specimen and conditions except dull finish; surface roughness $\sim 6$ microinches rms.  |
| 82        | 34       | 1957 | 375-1089             | $\sim 0^{\circ}$          | $\pm 10$          | Different sample, same as above specimen and conditions.  |
| 83        | 34       | 1957 | 561-761              | $\sim 0^{\circ}$          | $\pm 10$          | Above specimen and conditions; cycle 2.   |

SPECIFICATION TABLE NO. 389 (continued)

| Curve No. | Ref. No. | Year | Temperature Range, K | Geometry $\theta'$ | Reported Error, % | Composition (weight percent), Specifications and Remarks  |
|-----------|----------|------|----------------------|--------------------|-------------------|---|
| 84        | 34       | 1957 | 83.2                 | $\sim 0^\circ$     | $\pm 10$          | Different sample, same as curve 73 specimen and conditions except oxidized in air at red heat for 30 min; surface roughness $\sim 6$ microinches rms.   |
| 85        | 34       | 1957 | 594-1069             | $\sim 0^\circ$     | $\pm 10$          | Different sample, same as above specimen and conditions except increasing temp, cycle 1.  |
| 86        | 34       | 1957 | 544-789              | $\sim 0^\circ$     | $\pm 10$          | Above specimen and conditions; cycle 2.   |
| 87        | 34       | 1957 | 950                  | $\sim 0^\circ$     | $\pm 10$          | Above specimen and conditions; cycle 3.   |
| 88        | 34       | 1957 | 83.2                 | $\sim 0^\circ$     | $\pm 10$          | Stainless steel type AM 350; nominal composition: 16.50 Cr, 4.25 Ni, 2.75 Mo, 0.75 Mn, 0.35 Si, 0.10 C, 0.10 N, Fe balance; surface roughness $\sim 2$ microinches rms; measured in vacuum ( $5 \times 10^{-4}$ mm Hg). |
| 89        | 34       | 1957 | 422-605              | $\sim 0^\circ$     | $\pm 10$          | Different sample, same as above specimen and conditions except increasing temp, cycle 1.  |
| 90        | 34       | 1957 | 553-1200             | $\sim 0^\circ$     | $\pm 10$          | Above specimen and conditions; cycle 2.   |
| 91        | 34       | 1957 | 83.2                 | $\sim 0^\circ$     | $\pm 10$          | Different sample, same as curve 88 specimen and conditions except oxidized in air at red heat for 30 min.   |
| 92        | 34       | 1957 | 539-1022             | $\sim 0^\circ$     | $\pm 10$          | Different sample, same as above specimen and conditions except increasing temp, cycle 1.  |
| 93        | 34       | 1957 | 900-1161             | $\sim 0^\circ$     | $\pm 10$          | Above specimen and conditions; cycle 2.   |
| 94        | 170      | 1959 | 755-922              | $\sim 0^\circ$     |                   | Stainless steel 321; titanium stabilized 18 Cr, 8 Ni austenitic stainless steel; electropolished; computed from spectral data.  |
| 95        | 170      | 1959 | 755-1255             | $\sim 0^\circ$     |                   | Different sample, same as curve 94 specimen and conditions except also oxidized in air at 1255 K for 1/2 hr.  |
| 96        | 170      | 1959 | 755-922              | $\sim 0^\circ$     |                   | Different sample, same as curve 94 specimen and conditions except sandblasted by 40-mesh glass sand and air at 40 psi.  |
| 97        | 170      | 1959 | 755-1255             | $\sim 0^\circ$     |                   | Different sample, same as curve 94 specimen and conditions except also oxidized in air at 1255 K for 1/2 hr.  |
| 98        | 15       | 1947 | 373                  | $\sim 0^\circ$     |                   | Alleghany metal; nominal composition: 17-20 Cr, 7-10 Ni, 0.50 max Mn, 0.20 C, Fe balance; No. 4 polish.   |
| 99        | 157      | 1944 | 356-441              | $\sim 0^\circ$     |                   | Stainless steel 18-8; nominal composition: 18.45 Cr, 8.79 Ni, 0.50 Mn, 0.10 C, Fe balance; oxidized at 811 K; measured in air.  |
| 100       | 157      | 1944 | 350-435              | $\sim 0^\circ$     |                   | Different sample, same as curve 99 specimen and conditions except oxidized at 1089 K.   |
| 101       | 157      | 1944 | 351-446              | $\sim 0^\circ$     |                   | Different sample, same as curve 99 specimen and conditions except chromic and sulfuric blackened.   |
| 102       | 157      | 1944 | 355-456              | $\sim 0^\circ$     |                   | Different sample, same as curve 99 specimen and conditions except sand blasted.   |
| 103       | 155      | 1948 | 419-594              | $\sim 0^\circ$     |                   | Stainless steel 18-8; nominal composition: 18.45 Cr, 8.79 Ni, 0.50 Mn, 0.10 C, Fe balance; sand blasted and weathered.  |
| 104       | 155      | 1948 | 342-646              | $\sim 0^\circ$     |                   | Different sample, same as curve 103 specimen and conditions except oxidized at 1089 K and weathered.  |

SPECIFICATION TABLE NO. 389 (continued)

| Curve No. | Ref. No. | Year | Temperature Range, K | Geometry $\theta'$ | Reported Error, % | Composition (weight percent), Specifications and Remarks  |
|-----------|----------|------|----------------------|--------------------|-------------------|---|
| 105       | 155      | 1948 | 344-661              | $\sim 0^\circ$     |                   | Different sample, same as curve 103 specimen and conditions except chromic and sulphuric acid treated and weathered.  |
| 106       | 155      | 1948 | 455-650              | $\sim 0^\circ$     |                   | Different sample, same as curve 103 specimen and conditions except unpolished.  |
| 107       | 155      | 1948 | 353-655              | $\sim 0^\circ$     |                   | Different sample, same as curve 103 specimen and conditions.  |
| 108       | 155      | 1948 | 344-603              | $\sim 0^\circ$     |                   | Above specimen and conditions except polished with Aerobright and Bon Ami.  |
| 109       | 107      | 1960 | 644-1644             | $\sim 0^\circ$     | $\pm 20$          | Stainless steel 301; nominal composition: 16.00-18.00 Cr, 6.00-8.00 Ni, 2.00 Mn, 1.00 max Si, 0.15 max C, Fe balance; measured in demoisturized helium gas.   |
| 110       | 99       | 1958 | 366-699              | $\sim 0^\circ$     | < 9               | Type 321 corrosion-resistant steel; MIL-S-6721; nominal composition: 17.00-19.00 Cr, 9.00-12.00 Ni, 2.00 max Mn, 1.00 max Si, 0.08 max C, 5 x C min Ti, Fe balance; measured in air.  |
| 111       | 99       | 1958 | 366-699              | $\sim 0^\circ$     | < 9               | Different sample, same as curve 110 specimen and conditions except heated at 647 K for 1000 hrs.  |
| 112       | 99       | 1958 | 366-699              | $\sim 0^\circ$     |                   | Different sample, same as curve 110 specimen and conditions except calculated from spectral $\beta$ ( $2\pi, 0^\circ$ ).  |
| 113       | 99       | 1958 | 366-699              | $\sim 0^\circ$     |                   | Different sample, same as curve 112 specimen and conditions except heated at 647 K for 1000 hrs.  |
| 114       | 164      | 1961 | 1366                 | $\sim 0^\circ$     | $\pm 2.5$         | Stainless steel type 303; nominal composition: 17.00-19.00 Cr, 8.00-10.00 Ni, 2.00 max Mn, 1.00 max Si, 0.15 min S, 0.15 max C, Fe balance; mechanically polished and cleaned; oxidized in quiescent air at 1366 K for 10 min; measured in air. |
| 115       | 164      | 1961 | 1366                 | $\sim 0^\circ$     | $\pm 2.5$         | Above specimen and conditions except oxidized in quiescent air at 1366 K for 25 min.  |
| 116       | 164      | 1961 | 1366                 | $\sim 0^\circ$     | $\pm 2.5$         | Above specimen and conditions except oxidized in quiescent air at 1366 K for 40 min.  |
| 117       | 164      | 1961 | 1366                 | $\sim 0^\circ$     | $\pm 2.5$         | Above specimen and conditions except oxidized in quiescent air at 1366 K for 70 min.  |
| 118       | 40       | 1962 | 408-1061             | $\sim 0^\circ$     |                   | Cobalt alloy N-155 (surface N-1); nominal composition: 21 Cr, 20 Co, 20 Ni, 3 Mo, 3 W, 1.5 Mn, 1 Nb, 0.5 Si, 0.15 C, 0.15 N, Fe balance; as received; increasing temp.  |
| 119       | 40       | 1962 | 408-655              | $\sim 0^\circ$     |                   | Above specimen and conditions; decreasing temp.   |
| 120       | 40       | 1962 | 367                  | $\sim 0^\circ$     |                   | Different sample, same as curve 118 specimen and conditions except highly polished, mirror finish; oxide formation at 873 K for 3 hrs.  |
| 121       | 40       | 1962 | 447-1061             | $\sim 0^\circ$     |                   | Different sample, same as curve 118 specimen and conditions except surface N-2; increasing temp.  |
| 122       | 40       | 1962 | 1033-447             | $\sim 0^\circ$     |                   | Above specimen and conditions; decreasing temp.   |
| 123       | 40       | 1962 | 411-1084             | $\sim 0^\circ$     |                   | Different sample, same as curve 121 specimen and conditions except heat treated; same results for increasing and decreasing temp.   |
| 124       | 40       | 1962 | 352-564              | $\sim 0^\circ$     |                   | Poroloy (18-8 stainless steel); nominal composition: 18.45 Cr, 8.79 Ni, 0.50 Mn, 0.10 C, Fe balance; porosity between 28 and 31%.   |

SPECIFICATION TABLE NO. 389 (continued)

| Curve No. | Ref. No. | Year | Temperature Range, K | Geometry $\theta'$ | Reported Error, % | Composition (weight percent), Specifications and Remarks   |
|-----------|----------|------|----------------------|--------------------|-------------------|--|
| 125       | 40       | 1962 | 367                  | $\sim 0^\circ$     |                   | Different sample, same as above specimen and conditions except porosity 28%.   |
| 126       | 40       | 1962 | 367                  | $\sim 0^\circ$     |                   | Different sample, same as above specimen and conditions except porosity 31%.   |
| 127       | 40       | 1962 | 367                  | $\sim 0^\circ$     |                   | Different sample, same as above specimen and conditions except porosity 43%.   |
| 128       | 75       | 1962 | 811-1444             | $\sim 0^\circ$     |                   | Stainless steel 304; nominal composition: 18.00-20.00 Cr, 8.00-12.00 Ni, 2.00 max Mn, 1.00 max Si, 0.08 max C, Fe balance; machine finished; helium purge.   |
| 129       | 92       | 1963 | 1328-1466            | $\sim 0^\circ$     |                   | Haynes Alloy N-155 (Multimet); 23.98-36.15 Fe, 19-21 Ni, 18.5-21 Co, 20-22.5 Cr, 2-3 W, 0.75-1.25 Nb and Ta, 2.5-3.5 Mo, 1.0-2.0 Mn, 0.5 max Cu, 1.0 max Si, 0.03 max S, 0.04 max P, 0.1-0.2 N <sub>2</sub> , 0.08-0.16 C; polished; surface roughness 1 to 2 $\mu$ (RMS) measured with profilometer; measured in vacuum (3 to 4 $\times 10^{-4}$ mm Hg); 1st cycle. |
| 130       | 92       | 1963 | 1289-1600            | $\sim 0^\circ$     |                   | Above specimen and conditions; 2nd cycle.  |
| 131       | 92       | 1963 | 1239-1452            | $\sim 0^\circ$     |                   | Curve 129 specimen and conditions except oxidized.   |
| 132       | 273      | 1962 | 805-1442             | $\sim 0^\circ$     |                   | Stainless steel 304; nominal composition: 18.00-20.00 Cr, 8.00-12.00 Ni, 2.00 max Mn, 1.00 max Si, 0.08 max C, Fe balance; mechanical finish; measured in He gas.  |

DATA TABLE NO. 389 NORMAL TOTAL EMITTANCE OF [IRON + CHROMIUM + NICKEL +  $\Sigma X_1$ ] ALLOYS

 [Temperature, T, K; Emittance,  $\epsilon$ ]

| T                          | $\epsilon$ | T                           | $\epsilon$ | T                                  | $\epsilon$ | T                           | $\epsilon$ | T                           | $\epsilon$ | T                           | $\epsilon$ | T                                  | $\epsilon$ | T                           | $\epsilon$ | T                           | $\epsilon$ |
|----------------------------|------------|-----------------------------|------------|------------------------------------|------------|-----------------------------|------------|-----------------------------|------------|-----------------------------|------------|------------------------------------|------------|-----------------------------|------------|-----------------------------|------------|
| <u>CURVE 1</u>             |            | <u>CURVE 6</u>              |            | <u>CURVE 11<sup>a</sup>(cont.)</u> |            | <u>CURVE 16<sup>a</sup></u> |            | <u>CURVE 21<sup>a</sup></u> |            | <u>CURVE 25<sup>a</sup></u> |            | <u>CURVE 29<sup>a</sup>(cont.)</u> |            | <u>CURVE 36</u>             |            |                             |            |
| 573                        | 0.47       | 633                         | 0.85       | 1280                               | 0.577      | 526                         | 0.233      | 538                         | 0.314      | 423                         | 0.424      | 1183                               | 0.636      | 83.2                        | 0.033      |                             |            |
| 673                        | 0.48       | 713                         | 0.85       | 507                                | 0.557      | 707                         | 0.212      | 792                         | 0.312      | 319                         | 0.463      | 547                                | 0.497      |                             |            |                             |            |
| 773                        | 0.47       | 793                         | 0.87       | 1218                               | 0.547      | 908                         | 0.261      | 929                         | 0.330      | 359                         | 0.424      |                                    |            |                             |            | <u>CURVE 37</u>             |            |
| 873                        | 0.50       | 873                         | 0.86       | 505                                | 0.573      | 1067                        | 0.466      | 1051                        | 0.396      |                             |            |                                    |            |                             |            | <u>CURVE 30<sup>a</sup></u> |            |
|                            |            | 1053                        | 0.87       |                                    |            | 1128                        | 0.536      | 1160                        | 0.559      | <u>CURVE 26</u>             |            |                                    |            |                             |            | 603                         | 0.105      |
| <u>CURVE 2</u>             |            | <u>CURVE 7<sup>a</sup></u>  |            | <u>CURVE 12</u>                    |            | 1186                        | 0.640      | 1217                        | 0.663      | 574                         | 0.394      | 434                                | 0.324      | 758                         | 0.115      |                             |            |
| 633                        | 0.77       |                             |            | 697                                | 0.241      | 1258                        | 0.675      | 1321                        | 0.657      | 739                         | 0.398      | 303                                | 0.381      | 966                         | 0.170      |                             |            |
| 723                        | 0.79       | 583                         | 0.40       | 352                                | 0.301      | 469                         | 0.427      | 1397                        | 0.431      | 785                         | 0.414      |                                    |            | 1072                        | 0.225      |                             |            |
| 803                        | 0.80       | 683                         | 0.43       | 924                                | 0.315      | 1178                        | 0.708      | 1402                        | 0.362      | 919                         | 0.413      | <u>CURVE 31<sup>a</sup></u>        |            | 1161                        | 0.345      |                             |            |
| 873                        | 0.82       | 733                         | 0.44       | 1018                               | 0.344      | 485                         | 0.549      | 523                         | 0.331      | 1029                        | 0.426      |                                    |            | <u>CURVE 38</u>             |            |                             |            |
| 933                        | 0.83       | 783                         | 0.45       | 1080                               | 0.389      | 1185                        | 0.699      | 1164                        | 0.410      | 1045                        | 0.444      | 493                                | 0.367      |                             |            |                             |            |
| 1013                       | 0.85       | 833                         | 0.47       | 1133                               | 0.451      | 483                         | 0.502      | 1329                        | 0.552      | 1088                        | 0.458      | 661                                | 0.385      | 772                         | 0.225      |                             |            |
| 1073                       | 0.87       | 873                         | 0.49       | 1183                               | 0.477      |                             |            | 1350                        | 0.510      | 1098                        | 0.474      | 923                                | 0.437      | 1050                        | 0.225      |                             |            |
|                            |            |                             |            |                                    |            | <u>CURVE 17<sup>a</sup></u> |            | 533                         | 0.529      | 1191                        | 0.568      | 1017                               | 0.475      | 1161                        | 0.375      |                             |            |
| <u>CURVE 3</u>             |            | <u>CURVE 8</u>              |            | <u>CURVE 13<sup>a</sup></u>        |            |                             |            | 1329                        | 0.504      | 1173                        | 0.620      | 1111                               | 0.629      |                             |            |                             |            |
| 633                        | 0.79       | 633                         | 0.59       | 88.9                               | 0.245      | 310                         | 0.280      | 517                         | 0.517      | 1159                        | 0.639      | 1194                               | 0.696      | <u>CURVE 39<sup>a</sup></u> |            |                             |            |
| 713                        | 0.81       | 733                         | 0.65       | 214                                | 0.260      | 364                         | 0.285      | <u>CURVE 22<sup>a</sup></u> |            | <u>CURVE 27<sup>a</sup></u> |            | 1267                               | 0.705      | 800                         | 0.270      |                             |            |
| 793                        | 0.83       | 813                         | 0.66       | 364                                | 0.275      |                             |            |                             |            |                             |            | 525                                | 0.561      | 1003                        | 0.325      |                             |            |
| 883                        | 0.87       | 893                         | 0.67       |                                    |            | <u>CURVE 18</u>             |            | 432                         | 0.169      | 525                         | 0.394      | 548                                | 0.485      |                             |            |                             |            |
| 953                        | 0.85       | 963                         | 0.68       | <u>CURVE 14<sup>a</sup></u>        |            |                             |            | 314                         | 0.196      | 1192                        | 0.495      | 1151                               | 0.654      | <u>CURVE 40</u>             |            |                             |            |
| 1013                       | 0.88       | 1033                        | 0.71       |                                    |            | 623                         | 0.306      | 371                         | 0.176      | 1159                        | 0.637      | 550                                | 0.521      |                             |            |                             |            |
| 1073                       | 0.89       |                             |            | 464                                | 0.300      | 929                         | 0.405      |                             |            | 482                         | 0.493      | <u>CURVE 32</u>                    |            | 83.2                        | 0.041      |                             |            |
|                            |            | <u>CURVE 9</u>              |            | 706                                | 0.270      | 971                         | 0.457      | <u>CURVE 23<sup>a</sup></u> |            | 1177                        | 0.650      |                                    |            |                             |            | <u>CURVE 41</u>             |            |
| <u>CURVE 4<sup>a</sup></u> |            |                             |            | 872                                | 0.320      | 1043                        | 0.490      |                             |            | 474                         | 0.516      | 83.2                               | 0.058      |                             |            |                             |            |
| 663                        | 0.22       | 733                         | 0.86       | 947                                | 0.345      | 1114                        | 0.532      | 679                         | 0.174      |                             |            |                                    |            |                             |            |                             |            |
| 733                        | 0.24       | 803                         | 0.88       | 1114                               | 0.460      | 1221                        | 0.626      | 893                         | 0.203      | <u>CURVE 28<sup>a</sup></u> |            | <u>CURVE 33</u>                    |            | 544                         | 0.090      |                             |            |
| 783                        | 0.26       | 873                         | 0.88       | 1197                               | 0.580      |                             |            | 1029                        | 0.283      |                             |            |                                    |            | 819                         | 0.145      |                             |            |
| 853                        | 0.28       | 933                         | 0.93       | 1247                               | 0.620      | <u>CURVE 19<sup>a</sup></u> |            | 1127                        | 0.362      | 426                         | 0.150      | 461                                | 0.090      | 989                         | 0.160      |                             |            |
| 893                        | 0.28       | 993                         | 0.93       | 1347                               | 0.370      |                             |            | 1169                        | 0.431      | 303                         | 0.169      | 628                                | 0.125      | 1105                        | 0.215      |                             |            |
|                            |            | 1053                        | 0.94       | 556                                | 0.230      | 496                         | 0.329      | 1214                        | 0.594      | 370                         | 0.173      | 803                                | 0.130      | 1233                        | 0.275      |                             |            |
| <u>CURVE 5<sup>a</sup></u> |            |                             |            | 1206                               | 0.460      | 786                         | 0.319      | 1280                        | 0.629      |                             |            | 961                                | 0.155      |                             |            |                             |            |
|                            |            | <u>CURVE 10</u>             |            | 1189                               | 0.525      | 1164                        | 0.585      | 1300                        | 0.597      | <u>CURVE 29<sup>a</sup></u> |            | 1055                               | 0.235      | <u>CURVE 42<sup>a</sup></u> |            |                             |            |
| 573                        | 0.42       |                             |            | 1172                               | 0.690      | 510                         | 0.572      | 502                         | 0.226      | 532                         | 0.211      |                                    |            | 811                         | 0.190      |                             |            |
| 653                        | 0.40       | 414                         | 0.202      | 439                                | 0.440      | 1132                        | 0.663      | 1147                        | 0.282      | 719                         | 0.217      | <u>CURVE 34<sup>a</sup></u>        |            | 989                         | 0.240      |                             |            |
| 763                        | 0.42       | 312                         | 0.246      | 488                                | 0.400      | 504                         | 0.581      | 1327                        | 0.316      | 919                         | 0.232      |                                    |            |                             |            |                             |            |
| 853                        | 0.42       | 377                         | 0.240      | 1222                               | 0.630      |                             |            | 281                         | 0.262      | 1046                        | 0.281      | 533                                | 0.150      | <u>CURVE 43<sup>a</sup></u> |            |                             |            |
| 933                        | 0.46       |                             |            | 547                                | 0.540      | <u>CURVE 20</u>             |            |                             |            | 1170                        | 0.412      | 850                                | 0.125      |                             |            |                             |            |
| 993                        | 0.50       | <u>CURVE 11<sup>a</sup></u> |            |                                    |            | <u>CURVE 24<sup>a</sup></u> |            |                             |            | 1232                        | 0.553      |                                    |            | 911                         | 0.230      |                             |            |
| 1053                       | 0.52       | 531                         | 0.223      |                                    |            | 88.9                        | 0.260      | 206                         | 0.320      | 423                         | 0.368      | 1290                               | 0.624      | <u>CURVE 35<sup>a</sup></u> |            | 1108                        | 0.280      |
|                            |            | 1242                        | 0.487      | 412                                | 0.100      | 372                         | 0.305      | 318                         | 0.394      | 488                         | 0.388      | 522                                | 0.140      | <u>CURVE 44</u>             |            |                             |            |
|                            |            | 1239                        | 0.603      | 305                                | 0.145      |                             |            | 360                         | 0.368      | 1175                        | 0.607      | 537                                | 0.488      |                             |            | 83.2                        | 0.072      |

<sup>a</sup> Not shown on plot

DATA TABLE NO. 389 (continued)

| T               | €       | T                | €     | T               | €     | T                | €     | T                | €     | T                | €      | T                | €     | T                       | €     | T                | €      |
|-----------------|---------|------------------|-------|-----------------|-------|------------------|-------|------------------|-------|------------------|--------|------------------|-------|-------------------------|-------|------------------|--------|
| <u>CURVE 45</u> |         | <u>CURVE 53</u>  |       | <u>CURVE 61</u> |       | <u>CURVE 69*</u> |       | <u>CURVE 77*</u> |       | <u>CURVE 84</u>  |        | <u>CURVE 92</u>  |       | <u>CURVE 99*(cont.)</u> |       |                  |        |
| 680             | 0.165   | 425              | 0.091 | 444             | 0.093 | 83.2             | 0.045 | 83.2             | 0.036 | 83.2             | 0.155  | 539              | 0.155 | 394                     | 0.340 |                  |        |
| 905             | 0.235   | 519              | 0.103 | 489             | 0.105 |                  |       |                  |       |                  |        | 778              | 0.170 | 395                     | 0.348 |                  |        |
| 1025            | 0.265   | 628              | 0.116 | 600             | 0.106 | <u>CURVE 70*</u> |       | <u>CURVE 78</u>  |       | <u>CURVE 85</u>  |        | 891              | 0.255 | 396                     | 0.354 |                  |        |
| 1130            | 0.315   | 828              | 0.152 | 711             | 0.123 |                  |       |                  |       |                  |        | 1022             | 0.305 | 405                     | 0.347 |                  |        |
| 1205            | 0.335   |                  |       | 828             | 0.143 | 444              | 0.100 | 494              | 0.085 | 594              | 0.285  |                  |       |                         |       | 406              | 0.348  |
|                 |         | <u>CURVE 54*</u> |       |                 |       | 628              | 0.120 | 633              | 0.105 | 744              | 0.320  | <u>CURVE 93*</u> |       | 407                     | 0.358 |                  |        |
|                 |         | <u>CURVE 46*</u> |       |                 |       |                  |       | 775              | 0.115 | 844              | 0.355  |                  |       | 421                     | 0.346 |                  |        |
| 769             | 0.220   | 616              | 0.103 | 661             | 0.106 | <u>CURVE 71*</u> |       | 939              | 0.150 | 930              | 0.405* | 906              | 0.290 | 422                     | 0.341 |                  |        |
| 911             | 0.265   | 733              | 0.132 | 939             | 0.154 | 466              | 0.100 | 1011             | 0.260 | 1011             | 0.445  | 1005             | 0.345 | 423                     | 0.358 |                  |        |
|                 |         |                  |       | 816             | 0.153 | 1053             | 0.147 | 661              | 0.120 | 1139             | 0.415  | 1069             | 0.460 | 1161                    | 0.390 | 436              | 0.348  |
|                 |         | <u>CURVE 47*</u> |       | 878             | 0.172 |                  |       | 761              | 0.145 | 1205             | 0.440  | <u>CURVE 86*</u> |       | <u>CURVE 94</u>         |       | 438              | 0.364  |
| 611             | 0.150   | <u>CURVE 55*</u> |       |                 |       | 855              | 0.170 |                  |       | <u>CURVE 79*</u> |        | 544              | 0.300 | 755                     | 0.10  | 440              | 0.366  |
| 1289            | 0.280   |                  |       | 625             | 0.131 | 605              | 0.103 | <u>CURVE 72*</u> |       | 633              | 0.280  | 789              | 0.360 | 922                     | 0.18  | 441              | 0.366  |
|                 |         | <u>CURVE 48</u>  |       | 844             | 0.196 | <u>CURVE 64*</u> |       | 500              | 0.100 | 844              | 0.345  | <u>CURVE 87*</u> |       | <u>CURVE 95</u>         |       | <u>CURVE 100</u> |        |
| 83.2            | 0.022   | <u>CURVE 56*</u> |       | 478             | 0.103 | 700              | 0.145 | 955              | 0.360 |                  |        | 950              | 0.420 | 755                     | 0.65  | 350              | 0.628  |
|                 |         |                  |       | 722             | 0.126 | 961              | 0.255 |                  |       | 994              | 0.390  |                  |       | 922                     | 0.69  | 351              | 0.606  |
|                 |         | <u>CURVE 49</u>  |       | 83.2            | 0.022 |                  |       | 1016             | 0.390 | <u>CURVE 80*</u> |        | <u>CURVE 88</u>  |       | 1089                    | 0.74  | 352              | 0.644  |
| 333             | 0.085   | <u>CURVE 57*</u> |       |                 |       | 1116             | 0.490 |                  |       | 1116             | 0.490  |                  |       | 1255                    | 0.72  | 353              | 0.644* |
| 694             | 0.085   |                  |       | 616             | 0.101 | <u>CURVE 73*</u> |       | 728              | 0.320 | 83.2             | 0.161  |                  |       |                         |       | 364              | 0.642  |
| 955             | 0.160   | 472              | 0.046 |                 |       | 1061             | 0.425 |                  |       |                  |        | <u>CURVE 89*</u> |       | <u>CURVE 96*</u>        |       | 365              | 0.654  |
|                 |         | 666              | 0.053 | <u>CURVE 66</u> |       | 83.2             | 0.044 | <u>CURVE 81</u>  |       |                  |        | 422              | 0.110 | 755                     | 0.34  | 367              | 0.616  |
|                 |         | <u>CURVE 50*</u> |       | 755             | 0.057 |                  |       | 83.2             | 0.027 | <u>CURVE 74</u>  |        | 83.2             | 0.111 | 605                     | 0.125 | 369              | 0.624  |
| 661             | 0.090   | <u>CURVE 58</u>  |       |                 |       | 544              | 0.115 | <u>CURVE 82</u>  |       | <u>CURVE 90</u>  |        |                  |       | <u>CURVE 97</u>         |       | 372              | 0.624* |
| 866             | . 0.115 |                  |       | 444             | 0.049 | 889              | 0.160 |                  |       |                  |        | 755              | 0.68  |                         |       | 373              | 0.628* |
|                 |         | <u>CURVE 51*</u> |       | 683             | 0.053 | 494              | 0.080 | 1005             | 0.250 | 375              | 0.145  | 553              | 0.130 | 922                     | 0.75  | 382              | 0.645  |
|                 |         |                  |       | 778             | 0.056 | 678              | 0.090 | 1083             | 0.335 | 622              | 0.195  | 755              | 0.155 | 1089                    | 0.70  | 386              | 0.668  |
| 511             | 0.080   | 878              | 0.079 | 833             | 0.125 |                  |       |                  |       | 733              | 0.230  | 883              | 0.170 | 1255                    | 0.74  | 396              | 0.672  |
| 678             | 0.100   | 1000             | 0.101 | 1044            | 0.280 | <u>CURVE 75*</u> |       | 861              | 0.270 | 941              | 0.200  |                  |       |                         |       | 406              | 0.674  |
| 950             | 0.140   |                  |       |                 |       | 1222             | 0.400 |                  |       | 933              | 0.315  | 1044             | 0.240 | <u>CURVE 98*</u>        |       | 410              | 0.676* |
|                 |         | <u>CURVE 59*</u> |       |                 |       | 622              | 0.165 | 1000             | 0.423 | 1144             | 0.325  |                  |       |                         |       | 422              | 0.660  |
|                 |         | <u>CURVE 52</u>  |       |                 |       | 894              | 0.275 | 1089             | 0.465 | 1200             | 0.340  | 373              | 0.13  |                         |       | 423              | 0.654* |
| 83.2            | 0.044   | 650              | 0.052 |                 |       | <u>CURVE 68*</u> |       |                  |       | <u>CURVE 91*</u> |        | <u>CURVE 99*</u> |       | 432                     | 0.698 |                  |        |
|                 |         | 933              | 0.086 | 505             | 0.090 | <u>CURVE 76*</u> |       | <u>CURVE 83*</u> |       | <u>CURVE 91*</u> |        | <u>CURVE 99*</u> |       | 435                     | 0.712 |                  |        |
|                 |         |                  |       | 666             | 0.100 |                  |       |                  |       |                  |        | 356              | 0.312 |                         |       |                  |        |
|                 |         | <u>CURVE 60*</u> |       | 772             | 0.095 | 872              | 0.275 | 561              | 0.260 | 83.2             | 0.111  | 357              | 0.328 |                         |       |                  |        |
|                 |         |                  |       |                 |       | 1039             | 0.300 | 1044             | 0.350 | 761              | 0.345  |                  |       | 359                     | 0.314 |                  |        |
|                 |         |                  | 83.2  | 0.044           |       |                  | 1122  | 0.420            |       |                  |        |                  |       |                         |       |                  |        |

\* Not shown on plot

DATA TABLE NO. 389 (continued)

| T                | €      | T                        | €      | T                         | €     | T                 | €     | T                 | €     | T                 | €      |
|------------------|--------|--------------------------|--------|---------------------------|-------|-------------------|-------|-------------------|-------|-------------------|--------|
| <u>CURVE 101</u> |        | <u>CURVE 104 (cont.)</u> |        | <u>CURVE 107*</u> (cont.) |       | <u>CURVE 113</u>  |       | <u>CURVE 122</u>  |       | <u>CURVE 129*</u> |        |
| 351              | 0.560  | 528                      | 0.850  | 563                       | 0.203 | 366               | 0.33  | 1033              | 0.566 | 1328              | 0.230  |
| 391              | 0.570  | 577                      | 0.850  | 592                       | 0.200 | 477               | 0.34  | 683               | 0.410 | 1369              | 0.250  |
| 405              | 0.522  | 579                      | 0.845  | 611                       | 0.210 | 588               | 0.35  | 447               | 0.300 | 1466              | 0.245  |
| 418              | 0.560  | 646                      | 0.855  | 655                       | 0.205 | 699               | 0.36  |                   |       |                   |        |
| 433              | 0.524  |                          |        |                           |       |                   |       | <u>CURVE 123</u>  |       | <u>CURVE 130*</u> |        |
| 445              | 0.542  | <u>CURVE 105</u>         |        | <u>CURVE 108</u>          |       | <u>CURVE 114</u>  |       | 411               | 0.445 | 1289              | 0.205  |
| 446              | 0.560  | 344                      | 0.650  | 344                       | 0.155 | 1366              | 0.841 | 416               | 0.410 | 1354              | 0.220  |
| <u>CURVE 102</u> |        | 350                      | 0.670  | 433                       | 0.160 |                   |       | 677               | 0.510 | 1392              | 0.220  |
| 355              | 0.510  | 380                      | 0.610  | 528                       | 0.175 |                   |       | 844               | 0.570 | 1490              | 0.240  |
| 360              | 0.484  | 392                      | 0.605  | 603                       | 0.195 | 1366              | 0.867 | 1084              | 0.628 | 1549              | 0.250* |
| 364              | 0.510  | 397                      | 0.610* |                           |       |                   |       |                   |       | 1575              | 0.270* |
| 366              | 0.486  | 400                      | 0.640  | <u>CURVE 109</u>          |       | <u>CURVE 116</u>  |       | <u>CURVE 124</u>  |       | 1600              | 0.290* |
| 369              | 0.476  | 419                      | 0.625  |                           |       |                   |       | 352               | 0.23  | <u>CURVE 131*</u> |        |
| 370              | 0.504  | 428                      | 0.620  | 644                       | 0.09  | 1366              | 0.870 | 358               | 0.26  |                   |        |
| 377              | 0.500  | 433                      | 0.620* | 811                       | 0.16  |                   |       | 425               | 0.25  | 1239              | 0.720  |
| 383              | 0.486  | 436                      | 0.615  | 1089                      | 0.31  | <u>CURVE 117*</u> |       | 425               | 0.26* | 1255              | 0.730  |
| 383              | 0.508  | 442                      | 0.615* | 1367                      | 0.51  |                   |       | 469               | 0.26  | 1311              | 0.760  |
| 393              | 0.504  | 483                      | 0.610  | 1644                      | 0.72* | 1366              | 0.874 | 489               | 0.25  | 1355              | 0.780  |
| 395              | 0.506* | 525                      | 0.595  |                           |       |                   |       | 490               | 0.26  | 1452              | 0.700  |
| 404              | 0.511  | 533                      | 0.605  | <u>CURVE 110*</u>         |       | <u>CURVE 118</u>  |       | 491               | 0.26* |                   |        |
| 419              | 0.492  | 605                      | 0.630  |                           |       |                   |       | 530               | 0.26  | <u>CURVE 132*</u> |        |
| 425              | 0.524  | 608                      | 0.595  | 366                       | 0.31  | 408               | 0.165 | 564               | 0.26  |                   |        |
| 429              | 0.510  | 617                      | 0.600  | 477                       | 0.31  | 444               | 0.150 |                   |       | 805               | 0.135  |
| 435              | 0.522  | 661                      | 0.610  | 588                       | 0.31  | 683               | 0.175 | <u>CURVE 125*</u> |       | 808               | 0.161  |
| 438              | 0.518* |                          |        | 699                       | 0.33  | 891               | 0.155 |                   |       | 1128              | 0.477  |
| 444              | 0.484  | <u>CURVE 106*</u>        |        |                           |       | 1061              | 0.550 | 367               | 0.23  | 1402              | 0.711  |
| 456              | 0.484  |                          |        | <u>CURVE 111*</u>         |       |                   |       |                   |       | 1442              | 0.722  |
|                  |        | 455                      | 0.205  |                           |       | <u>CURVE 119*</u> |       | <u>CURVE 126*</u> |       |                   |        |
| <u>CURVE 103</u> |        | 472                      | 0.170  | 366                       | 0.31  |                   |       |                   |       |                   |        |
|                  |        | 542                      | 0.225  | 477                       | 0.33  | 408               | 0.225 | 367               | 0.23  |                   |        |
| 419              | 0.850  | 550                      | 0.204  | 588                       | 0.31  | 655               | 0.338 |                   |       |                   |        |
| 422              | 0.825  | 583                      | 0.210  | 699                       | 0.33  |                   |       | <u>CURVE 127*</u> |       |                   |        |
| 458              | 0.850  | 594                      | 0.230  |                           |       | <u>CURVE 120*</u> |       |                   |       |                   |        |
| 475              | 0.845  | 632                      | 0.220  | <u>CURVE 112</u>          |       |                   |       | 367               | 0.32  |                   |        |
| 594              | 0.845  | 650                      | 0.225  |                           |       | 366               | 0.36  |                   |       | <u>CURVE 128</u>  |        |
| <u>CURVE 104</u> |        | <u>CURVE 107*</u>        |        | 477                       | 0.37  | <u>CURVE 121</u>  |       | 811               | 0.145 |                   |        |
|                  |        |                          |        | 588                       | 0.38  |                   |       |                   |       |                   |        |
| 342              | 0.855  | 353                      | 0.180  | 699                       | 0.39  | 447               | 0.190 | 811               | 0.175 |                   |        |
| 353              | 0.845  | 380                      | 0.170  |                           |       | 722               | 0.220 | 1128              | 0.480 |                   |        |
| 394              | 0.940  | 414                      | 0.180  |                           |       | 855               | 0.290 | 1400              | 0.720 |                   |        |
| 425              | 0.840  | 503                      | 0.190  |                           |       | 916               | 0.325 | 1444              | 0.730 |                   |        |
| 453              | 0.850  | 539                      | 0.195  |                           |       | 964               | 0.400 |                   |       |                   |        |
|                  |        |                          |        |                           |       | 1061              | 0.600 |                   |       |                   |        |

\* Not shown on plot

## DATA ANALYSIS

The objective of the Analyzed Data Graphs is to give the user an evaluative review of available experimental data. It is quite apparent from a study of data sheets of the previous section that the analysis effort is first a filtering process; it identifies the data which are felt to be reliably or typically identified with the materials and gives the user a good deal of "relief" from the "spaghetti" type of presentation shown on the original or archival graphs. However, even these original graphs are the result of some filtering where grossly uncharacterized and second hand data sources have not been included. For certain circumstances of surface preparation and/or environmental conditions, data can be used with some degree of confidence but a great deal of data can only be considered as typical within certain limits.

The procedure for generating the Analyzed Data Graph varies according to the experimental evidence available for all the related sub-properties of the material being studied. Where there is some assurance that the data are well characterized and can be used with some confidence in engineering applications, the analyzed curve is shown as a solid line. A dotted line curve is used for reasonable extrapolations of well characterized conditions and for conditions felt to be typical and as such should be used with some caution. Shaded areas between solid lines are indicative of the limits in which so-called "typical" data will be found.

Each of the curves or areas is identified by key words which are felt descriptive of the surface conditions, etc.; frequently, these words are seen to be incomplete descriptions and the user will find it necessary, if not desirable in all cases, to consult the specification tables for a more complete description of the test conditions being represented. For this reason, the analyzed data graphs show the original curve number identifying the particular set(s) of data used to derive the analyzed curve.

In the SERIES Volume 7 nearly 25 percent of the data will be represented in analyzed or evaluated form. The sample figures presented in the previous section are some extreme examples selected to demonstrate the variety of approaches used to increase the value of the data to the user. The subsequent remarks on the data sheets of the previous section should give the reader of the

report some appreciation for the procedure/technique used in the data evaluation work.

ALUMINUM - For nearly all the materials, one of the first sets of data to be identified is the ideal surface conditions typified by the terms evaporated films for this material (and also electropolished for other materials to be discussed); the curves 4, 5, 15 and 29 when combined, and also interpolated in the near UV, give the reflectivity of well prepared "evaporated films". Bulk material polished by various techniques is identified by the broad band "polished" according to curves 9, 20 and 26; curve 17, the only visible data, also labeled "polished", is represented by a dashed line since it is uncharacterized data. The other curves on the same figure are all represented by solid lines because the surface conditions are characterized, could possibly be reproduced, and would be useful for many engineering applications.

COPPER - The figure for the normal spectral absorptance (room temperature) demonstrates the use of simply related sub-property data; in this case the results of analysis on the reflectance has been used to generate the absorptance in the visible region. The surface conditions - "electropolished & films" - for original measurements of both reflectance and absorptance have been evaluated to give a consistent recommended curve. The other curve on the figure labeled "mechanically polished, 6" demonstrates the influence of polishing techniques on the sub-property. Other data is shown on the original data sheet, but is seen to lack any particular value in demonstrating an effect or trend.

GALLIUM - The spectral transmittance data for this material has been presented in a hybrid manner; it is indicative of our philosophy to present the data based upon technical clarity. The measurements have been grouped into two figures distinguishing the high and low evaporation rate data. The curves are represented by the original data points and identified only by curve number. This data has not really been analyzed in depth but rather it has been filtered based upon some evaporation rate considerations. The reader has the obligation of labeling the curves as he sees fit and also of determining the reliability of the data which is not apparent without some other supporting data.

MOLYBDENUM - The analyzed data graph for the hemispherical total emittance demonstrates the effective use of bands indicative of limits of an effect, in this

case, for "polished" and "grit blasted conditions". It is assumed for all these curves an attempt is made to retard oxidation; this is the general case unless otherwise specified. The "stably oxidized at 811 K, 3" curve has a note warning the user about an extrapolation to higher temperatures in a vacuum; this note is not based upon data at hand, but rather reflects the experience of the analysis workers.

TUNGSTEN - This graph for the normal spectral emittance shows separately the very special case of "annealed aged ribbon" as commonly found in strip lamps or otherwise can be readily obtained and prepared; this data has its special uses and deserves to be distinguished from other types of specimens. The remaining data is analyzed in a manner consistent with the previous materials. It is especially interesting to note that the most significant information in 97 original data curves has been very concisely shown on one uncluttered graph.

STAINLESS STEEL - The original data graph for the normal total emittance contains 132 curves for measurements on the various alloys in extreme variations of surface conditions; it is understandable that the curves range in emittance from 0 to 1 and fill the whole graph. The first step in the analysis effort was to separate the data into three major groups: polished, cleaned and oxidized. It was quickly apparent that the influence of composition or alloy identification was lost by comparison to environmental effects; the exception to this in N-155. The remaining steps in the analysis procedure were to identify typical conditions.

#### SUMMARY

This report has described in some detail the problems and progress of a comprehensive program for the compilation and analysis of thermal radiative properties data. The procedures for compilation of the literature - an operation in scientific documentation and data extraction - draws upon the experience of TPRC as an information center\*. The analysis work is an evaluative review of the literature attempting to filter out data thought to be of little value and to "recommend" data which is of engineering application use.

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\* Appendix E, TPRC-Information Center for Thermophysics Research, discusses in some detail the objective and activities of TPRC.

The results of this program will be available as the TPRC SERIES, a collection of three volumes distributed as a commercial publication. With an audience of diversified interests and backgrounds, the SERIES has been designed to be authoritative and yet simple to use; the need for this reference work has necessarily caused a compromise between availability and completeness of coverage. A special feature of this publication, quite distinctive from other data sources or handbooks, is the continuing program to upgrade or maintain its coverage current and the user can always get the "last word" from the SERIES generator, TPRC.

A program of this magnitude with such wide objectives can benefit from the reaction of the technical community. Reaction to the SERIES is very much desired whether it be technical in nature or in regard to the organization or structure. A technical problem of current concern is the Classification Scheme for Coatings. The program can also benefit from personal assistance of specialists in this field - as new papers or reports are generated they should be forwarded to TPRC for their immediate addition to the System; in this direct and simple manner, the coverage can be made current.

#### REFERENCES

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## **APPENDIX A**

### **Table of Contents**

**TPRC Series, Volume 7  
Thermal Radiative Properties  
of  
Metallic Elements and Alloys**



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### THEORY, ESTIMATION AND MEASUREMENT

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## **APPENDIX B**

**Sub-property Nomenclature, Definitions,  
and Classification**

**TPRC Series, Volume 7  
Thermal Radiative Properties  
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## 1.0 Primary Property Definitions

The primary radiation properties -- emittance, reflectance, absorptance, and transmittance -- are all dimensionless quantities descriptive of the radiant energy transport process. They are defined as follows:

|               |  |
|---------------|--|
| Emittance     | ratio of the emitted flux per unit area to that of a blackbody radiator at the same temperature, and the same wavelength and geometric viewing conditions. |
| Reflectance   | ratio of some specified portion of the reflected radiant flux to the incident radiant flux.  |
| Absorptance   | ratio of the absorbed radiant flux to the incident radiant flux.   |
| Transmittance | ratio of some specified portion of the transmitted radiant flux to the incident radiant flux.  |

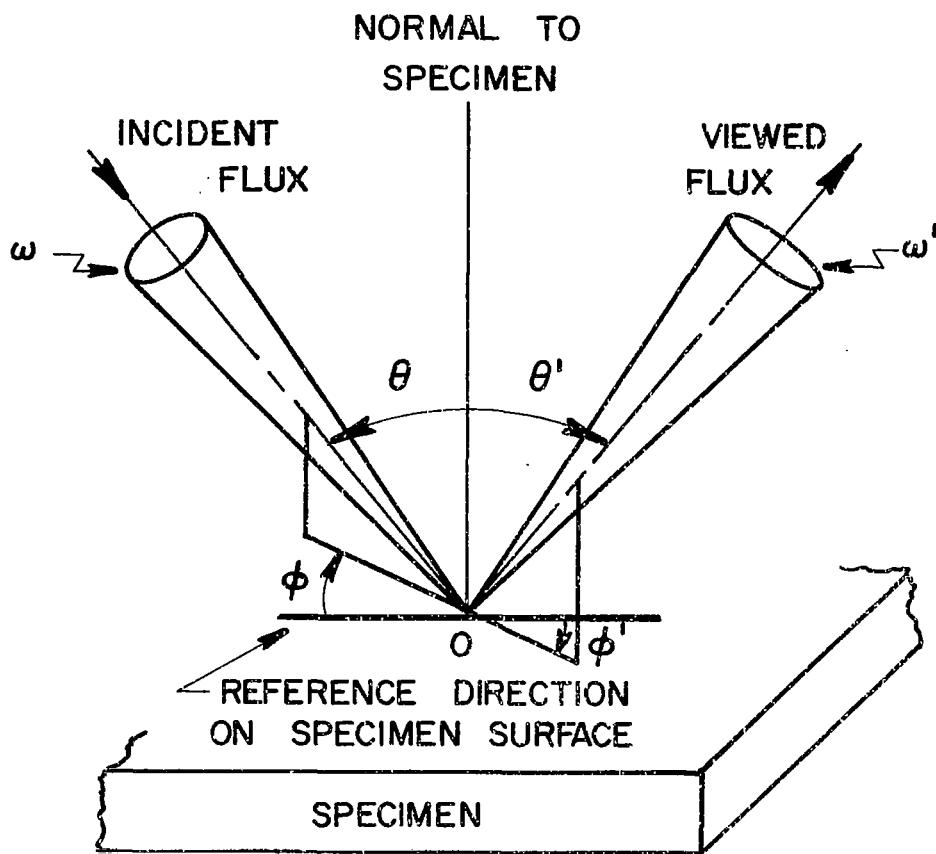
To present the data in a more concise form for efficient retrieval, the primary properties are further categorized into sub-properties. Since there is no universally accepted nomenclature for this division, it has been necessary to develop a consistent set of terms to unambiguously represent the various sub-properties. For the most part, the nomenclature, fully described in the next section, approximates common usage and lends itself well to the compact and systematic organization required of such comprehensive work.

## 2.0 Sub-Property Designation

Each of the primary properties needs to be further specified by descriptors indicating the geometry of the incident and/or viewing conditions, and the wavelength condition. It is the convention here to list these descriptors in the following order: geometry of incidence (or viewing) and wavelength condition. The terminology of these descriptors is now further discussed.

### 2.1 Geometry descriptors

These descriptors designate the geometric conditions of incidence and/or viewing (in that order) under which the sample is being observed. Figure B-1 defines the six (6) parameters required to completely specify the incidence and viewing conditions.



- $\theta$  Zenith Angle or Co-Latitude,  $^{\circ}$
- $\phi$  Azimuthal Angle or Longitude,  $^{\circ}$
- $\omega$  Beam Solid Angle, Steradians
- ' (Prime) Refers to Viewing Conditions

FIGURE B-1. NOTATION FOR DESCRIBING GEOMETRIC CONDITIONS

For the purpose of categorizing the various sub-properties, the following three terms are used as the geometric descriptors for all of the primary properties.

|               |   |
|---------------|---|
| Angular       | conditions for incidence and/or viewing through a solid angle (steradians) $\omega$ and/or $\omega'$ at some direction specified by $\theta$ or $\theta'$ $\geq 15^\circ$ .       |
| Normal        | conditions for incidence and/or viewing through a solid angle $\omega$ and/or $\omega'$ , nearly normal to the specimen (to be interpreted as $\theta$ or $\theta' < 15^\circ$ ). |
| Hemispherical | conditions for incidence and/or viewing the flux over a hemispherical region; beam geometry, $\omega$ or $\omega'$ indicated as $2\pi$ .  |

The selection of these descriptors is at best a compromise with standard practice and convenience. For emittance and absorptance, only one beam need be specified - viewing and incidence respectively. For reflectance and transmittance, the geometry of two beams must be specified. However, for convenience it is desirable to group the reflectance and transmittance data as follows: those sub-properties with common incidence geometric descriptors are grouped together.

The grouping of reflectance and transmittance sub-properties by common incidence conditions deserves some explanation. A grouping scheme is desirable to reduce the physical size of the book, and equally important, to bring together simply related sub-properties allowing the user to locate fragments of data that can be put together to generate information not found directly. For example, if one desires information on normal emittance or normal absorptance, it can easily be calculated from the following equation under certain conditions.

$$\epsilon(0^\circ) = \alpha(0^\circ) = 1 - \rho(0^\circ, 2\pi) - \tau(0^\circ, 2\pi)$$

If the sample is opaque, the equation simplifies to

$$\epsilon(0^\circ) = \alpha(0^\circ) = 1 - \rho(0^\circ, 2\pi)$$

and the calculation can be made by simply using normal reflectance.

"Reflectance factor" data is classified according to the sub-property of reflectance which it most nearly approximates. For instance, consider a reflectometer which hemispherically (diffusely), illuminates a specimen and views normally through a small solid angle. If the reflectometer then determines the ratio of the reflected flux from the specimen to that reflected from a perfect diffusing standard, the sub-property is the reflectance factor,  $\beta(2\pi, 0^\circ)$ . This is numerically equal to the reflectance sub-property  $\rho(0^\circ, 2\pi)$ . Such data is included in the "normal" category and a note added that it is in reality a reflectance factor.

## 2.2 Wavelength descriptors

These descriptors indicate spectrum conditions for which the observations are reported. They are:

|            |  |
|------------|--|
| Spectral   | nearly monochromatic or a very narrow band   |
| Total      | relative to blackbody wavelength distribution; applicable only to emittance                  |
| Integrated | relative to some specified wavelength distribution of the irradiating source or a broad band |
| Solar      | relative to the wavelength distribution of the sun, natural or simulated                     |

The terms "spectral", "total" and "solar" are in common use and need little justification, the last term being a special case of "integrated", separately categorized because of the great current interest in solar property data.

The term "integrated" is a compromise as it has not been used extensively in the literature. The intent here is to group under this term data for broad wavelength bands, over spectral regions of a source, etc. A synonym for this term could be heterochromatic.

## 3.0 Sub-Property Groupings

The following Table B-1 lists the grouping of the various sub-properties that are presented in the book. This shows that thirty-three (33) sub-properties are classified for retrieval and organizational purposes. The amount of existing data for some of these sub-properties is quite small, but there are good

reasons to present the data using this generalized scheme. First, the clarity of presentation is better by not grouping together data which logically are unrelated. Also, this scheme lends itself especially well to up-dating and expansion in the future.

TABLE B-1. SUB-PROPERTY DESIGNATION

EMITTANCE

Hemispherical Total Emittance  
 Normal Total Emittance  
 Angular Total Emittance  
 Hemispherical Spectral Emittance  
 Normal Spectral Emittance  
 Angular Spectral Emittance

REFLECTANCE\*

Hemispherical Integrated Reflectance  
 Normal Integrated Reflectance  
 Angular Integrated Reflectance  
 Hemispherical Spectral Reflectance  
 Normal Spectral Reflectance  
 Angular Spectral Reflectance  
 Hemispherical Solar Reflectance  
 Normal Solar Reflectance  
 Angular Solar Reflectance

ABSORPTANCE

Hemispherical Integrated Absorptance  
 Normal Integrated Absorptance  
 Angular Integrated Absorptance  
 Hemispherical Spectral Absorptance  
 Normal Spectral Absorptance  
 Angular Spectral Absorptance  
 Hemispherical Solar Absorptance  
 Normal Solar Absorptance  
 Angular Solar Absorptance

TRANSMITTANCE\*

Hemispherical Integrated Transmittance  
 Normal Integrated Transmittance  
 Angular Integrated Transmittance  
 Hemispherical Spectral Transmittance  
 Normal Spectral Transmittance  
 Angular Spectral Transmittance  
 Hemispherical Solar Transmittance  
 Normal Solar Transmittance  
 Angular Solar Transmittance

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\*The geometry descriptors refer to the conditions of the incident radiant flux.

## **APPENDIX C**

**Material Index  
and  
Grouping of Materials and List  
of Figures and Tables**

**TPRC Series, Volume 7  
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Metallic Elements and Alloys**

## MATERIAL INDEX

## Index

## Index

| Sub-property code                             | EMITTANCE     |        |               |         |               |        | REFLECTANCE   |         |               |        |               |        | ABSORPTANCE   |        |               |        |               |        | TRANSMITTANCE |        |               |        |               |         |               |    |
|---|---------------|--------|---------------|---------|---------------|--------|---------------|---------|---------------|--------|---------------|--------|---------------|--------|---------------|--------|---------------|--------|---------------|--------|---------------|--------|---------------|---------|---------------|----|
|   | Total         |        | Spectral      |         | Integrated    |        | Spectral      |         | Solar         |        | Integrated    |        | Spectral      |        | Solar         |        | Integrated    |        | Spectral      |        | Solar         |        |               |         |               |    |
|   | Hemispherical | Normal | Hemispherical | Angular | Hemispherical | Normal | Hemispherical | Angular | Hemispherical | Normal | Hemispherical | Angular |               |    |
| Material Name                                 |               |        |               |         |               |        |               |         |               |        |               |        |               |        |               |        |               |        |               |        |               |        |               |         |               |    |
| Aluminum bronze . . . . .                     | -             | 1097   | -             | -       | 1100          | -      | -             | -       | -             | 1104   | -             | -      | -             | -      | -             | -      | -             | 1107   | -             | -      | -             | -      | -             | -       |               |    |
| Aluminum + Cobalt . . . . .                   | -             | -      | -             | -       | -             | -      | -             | -       | -             | 837    | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -       |               |    |
| Aluminum + Copper + $\Sigma X_i$ .            | 1003          | 1006   | -             | -       | 1010          | -      | -             | 1013    | -             | 1017   | -             | -      | 1023          | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -       |               |    |
| Aluminum + Iron + $\Sigma X_i$ .              | -             | -      | -             | -       | -             | -      | -             | -       | -             | 1029   | -             | -      | 1032          | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -       |               |    |
| Aluminum + Magnesium . . . . .                | -             | -      | -             | -       | -             | -      | -             | -       | -             | 840    | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -       |               |    |
| Aluminum + Magnesium + $\Sigma X_i$ . . . . . | 1039          | 1041   | -             | -       | -             | -      | -             | 1044    | -             | 1047   | -             | -      | -             | -      | -             | -      | -             | -      | 1052          | -      | -             | -      | -             | -       |               |    |
| Aluminum + Manganese + $\Sigma X_i$ . . . . . | 1054          | 1056   | -             | -       | -             | -      | -             | -       | -             | 843    | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -       |               |    |
| Aluminum + Silicon . . . . .                  | -             | -      | -             | -       | -             | -      | -             | -       | -             | 846    | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -       |               |    |
| Aluminum + Silver . . . . .                   | -             | -      | -             | -       | -             | -      | -             | -       | -             | 846    | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -       |               |    |
| Aluminum + Zinc + $\Sigma X_i$ . . .          | 1058          | 1060   | -             | -       | 1063          | 1066   | -             | 1069    | -             | -      | -             | -      | 1072          | -      | -             | -      | -             | -      | 1074          | -      | -             | -      | -             | -       | -             |    |
| Antimony . . . . .                            | -             | -      | -             | -       | -             | -      | -             | -       | -             | 61     | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | 64      |               |    |
| Armco Iron . . . . .                          | 291           | 294    | -             | -       | -             | -      | -             | 304     | -             | 306    | 311           | -      | -             | -      | -             | -      | -             | -      | 322           | -      | -             | -      | -             | -       | -             |    |
| Astrolloy . . . . .                           | -             | -      | -             | -       | -             | 1303   | -             | -       | -             | 1318   | -             | -      | 1352          | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -       | -             |    |
| AZ-31 . . . . .                               | -             | 1268   | -             | -       | -             | -      | -             | 1271    | -             | 1278   | -             | -      | -             | -      | -             | -      | -             | -      | 1280          | -      | -             | -      | -             | -       | -             |    |
| AZ-31B . . . . .                              | -             | -      | -             | -       | -             | -      | -             | -       | -             | 1274   | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -       |               |    |
| Barium . . . . .                              | -             | -      | -             | -       | -             | -      | -             | -       | -             | 66     | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | 82      |               |    |
| Beryllium . . . . .                           | -             | 69     | -             | -       | 72            | -      | -             | 76      | -             | 78     | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -       | -             |    |
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| Sub-property code                                    | Material Name | EMITTANCE     |        |               |         |               |        | REFLECTANCE   |        |               |        |               |        | ABSORPTANCE   |        |               |        |               |        | TRANSMITTANCE |        |               |        |               |        |               |  |
|--|---------------|---------------|--------|---------------|---------|---------------|--------|---------------|--------|---------------|--------|---------------|--------|---------------|--------|---------------|--------|---------------|--------|---------------|--------|---------------|--------|---------------|--------|---------------|--|
|  |               | Total         |        | Spectral      |         | Integrated    |        | Solar         |        | Integrated    |        | Spectral      |        | Solar         |        | Integrated    |        | Spectral      |        | Solar         |        | Integrated    |        | Spectral      |        | Solar         |  |
|  |               | Hemispherical | Normal | Hemispherical | Angular | Hemispherical | Normal | Hemispherical |  |
| Iron + Nickel . . . . .                              |               | -             | -      | -             | -       | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             |  |
| Iron + Nickel + $\Sigma X_i$ . . . . .               |               | -             | -      | -             | -       | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             |  |
| Iron + Nickel + Chromium<br>+ $\Sigma X_i$ . . . . . | 1258          | -             | -      | -             | -       | 1261          | -      | -             | -      | -             | -      | 1264          | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             |  |
| Iron + Tungsten . . . . .                            |               | -             | -      | -             | -       | -             | -      | 893           | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             |  |
| K Monel . . . . .                                    |               | -             | -      | -             | -       | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             |  |
| KR Monel . . . . .                                   |               | -             | -      | -             | -       | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             |  |
| Kaiser foil . . . . .                                |               | 2             | 3      | -             | -       | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             |  |
| Kanthal . . . . .                                    |               | -             | -      | -             | -       | -             | -      | 1128          | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             |  |
| Kanthal A . . . . .                                  |               | -             | -      | -             | -       | -             | -      | 1128          | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             |  |
| Konel . . . . .                                      | 1342          | -             | -      | -             | -       | -             | -      | 1345          | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             |  |
| Kovar . . . . .                                      |               | -             | -      | -             | -       | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             |  |
| L34 . . . . .  |               | -             | -      | -             | -       | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             |  |
| L72 . . . . .  |               | -             | -      | -             | -       | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             |  |
| L120 Magnesium . . . . .                             |               | -             | -      | -             | -       | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             |  |
| Lead . . . . .                                       | 324           | 326           | -      | -             | -       | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             |  |
| Lead + Tin . . . . .                                 | 896           | -             | -      | -             | -       | -             | -      | -             | -      | -             | -      | 336           | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             |  |
| Lutetium . . . . .                                   | -             | -             | -      | -             | -       | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             | -      | -             |  |

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## APPENDIX D

### References to Data Sources

TPRC Series, Volume 7  
Thermal Radiative Properties  
of  
Metallic Elements and Alloys

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| 129         | 36483  |
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| 132         | 23741  |
| 133         | 7159   |
| 134         | 7538   |
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| 138         | 19294  |
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## **APPENDIX E**

**TPRC - Information Center for  
Thermophysics Research**

## 1.0 Introduction

The overall activities of the Thermophysical Properties Research Center (TPRC) are divided into four areas: namely, (1) Scientific Documentation, (2) Generation of Data Tables, (3) Experimental Research, and (4) Theoretical Research. Since 1957, TPRC has contributed much to the knowledge of the thermophysical properties of pure and engineering materials [4]. Its results are disseminated at large in the form of two major publications: the Retrieval Guide and the Data Book.

Previously, the Retrieval Guide was published by McGraw-Hill Book Co., Volume 1 in 1960 and Volume 2 in 1963. Early in 1967, as Volume 3 of the Retrieval Guide was nearing completion, it was decided to publish a single comprehensive volume of this work thus merging the earlier Volumes 1 and 2 with the completed Volume 3. This merged, revised, and enlarged edition of the Retrieval Guide (**THERMOPHYSICAL PROPERTIES RESEARCH LITERATURE RETRIEVAL GUIDE**) was published in October 1967 by the Plenum Publishing Corporation. This definitive work contains a complete coverage of the world literature published from 1920 (in many cases earlier) to June 1964 on thirteen thermophysical properties. Its 2,800 pages (in 3 books) report 45,116 materials, citing 33,700 references representing 26,562 authors and 3,600 separate scientific and technical journals and books in addition to Government reports. Thus, the new Retrieval Guide brings to the scientific and technical community a single reference work heretofore thought impractical to generate. Effective with the completion of this work, the scope of coverage of the Retrieval Guide has been increased to sixteen properties. Furthermore, each property is coded separately instead of by groups.

The TPRC Data Book brought together the available data on the thermophysical properties of materials to provide for engineers and scientists the most comprehensive and authoritative reference data sources. Whenever possible, the recommended "most probable values" of particular properties for particular materials are also included. The original Data Book consisted of loose-leaf data sheets (11" x 17" in size) organized into three volumes. The data sheets constituted the final formal outlet of all TPRC data tables activities on all of its programs. As of December 1966, the Data Book contained 3,322 sheets, reporting 11,425 test specimens and citing 3,424 references.

In view of the continuing rapid growth of this work since 1960, and the extensive physical proportions it has assumed, early in 1967 it was decided to discontinue the procedure of publication in loose-leaf format, and its semi-annual dissemination by TPRC.

Instead, this Data Book is now restructured and extensively revised and will soon be available through a commercial publisher in the form of formal hard-bound volumes grouped by properties. This forthcoming publication is entitled TPRC SERIES ON THERMOPHYSICAL PROPERTIES OF MATTER.

The information processing and data processing for preparing the Retrieval Guide and the Data Book and the status of the various active projects are outlined briefly in the following sections. The activities of Data Tables Division pertaining to the generation of data tables on thermal radiative properties have been described in the text of this report.

## 2.0 Scientific Documentation

### 2.1 Literature Search and Information Processing

The Scientific Documentation Division of TPRC provides comprehensive and authoritative source information on the thermophysical properties of all matter through continuing and systematic search, collection, organization, and codification of the existing information in the world literature. From 1957 to 1964 TPRC has searched the world literature primarily through the abstracting journals. Since 1965, TPRC has subscribed to some 80 scientific and technical journals in addition to the abstracting journals, and accordingly, literature search has since been made on both of these two types of journals.

The abstracting journals searched from 1957 to 1964 are listed in Table E-1. This search, covering the period from 1920 to June 1964, involved the scanning of approximately 33,400,000 abstracts out of approximately 81,000,000 abstracts reported by these journals. Out of the 33,400,000 abstracts scanned, only 52,500 (0.16%) were considered pertinent. Subsequent examination and checking of the 52,500 abstracts and the original papers revealed a large number of duplications between the various abstracting journals and nearly 9,900 irrelevant ones, leaving a net total of 28,800 documents obtained from these sources. In addition to abstracts, 4,900 documents came to TPRC's attention from other sources making a total of 33,700

TABLE E-1. WORLD COVERAGE OF RESEARCH LITERATURE ON THERMOPHYSICAL PROPERTIES THROUGH THE EYES OF 16 ABSTRACTING JOURNALS

(As of December 31, 1964)

| ABSTRACTING JOURNALS   | COVERAGE  |
|--|---|
| Applied Mechanics Review (AM)                                      | Jan. 1948 to June 1964                                |
| ASM Review of Current Metal Literature<br>(in Metals Review) (MR)* | Jan. 1957 to Aug. 1959                                |
| ASM Review of Metal Literature (RM)                                | Jan. 1944 to Dec. 1955 and<br>Jan. 1959 to June 1964  |
| Battelle Technical Review (BR)                                     | Feb. 1957 to June 1964                                |
| Ceramics Abstracts-Amer. Ceramic Soc. (JA)                         | Jan. 1957 to June 1964                                |
| Ceramics Abstracts-Brit. Ceramic Soc. (BA)                         | Jan. 1958 to June 1964                                |
| Chemical Abstracts (CA)  | Jan. 1920 to June 1964                                |
| Masters Theses in the Pure and Applied<br>Sciences - TPRC(MT)      | 1957 to 1964  |
| Metallurgical Abstracts, Series II (MA)                            | Jan. 1934 to Aug. 1956 and<br>Sept. 1958 to June 1964 |
| Nuclear Science Abstracts (NA)                                     | Jan. 1963 to June 1964                                |
| Physics Abstracts (SA)   | Jan. 1957 to June 1964                                |
| Refrigeration Abstracts (RA)                                       | Jan. 1946 to Oct. 1957                                |
| Scientific and Technical Aerospace Reports-NASA (PA)               | Jan. 1957 to June 1964                                |
| Technical Abstract Bulletin-DDC (TA)*                              | Jan. 1957 to June 1964                                |
| Technical Translations-CFSTI (TT)*                                 | Jan. 1957 to June 1964                                |
| U. S. Government Research Reports-CFSTI (RR)                       | Jan. 1957 to June 1964                                |

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\*Ceased publication

documents up to June 1964. These 33,700 references are covered in the revised and expanded edition of the Retrieval Guide.

Subsequently, in preparation for the future volume of the Retrieval Guide, an additional 17,300 reference entries have been made. Thus, as of 31 December 1968 there were 51,000 references in TPRC's Information storage and Retrieval System. The above figure gives an insight as to the magnitude of the effort involved in a thorough search of world knowledge even in a relatively specialized field.

When the retrospective search of the world literature, primarily through the medium of abstracting journals, was completed early in 1956, TPRC reviewed its procedure of using abstracting journals for the identification of current literature on thermophysical properties research. It was recognized that continued use of abstracting journals for research awareness would represent, at best, one to two years of delay in identifying and procuring such literature, with the result that bibliographic searches provided by TPRC could never be on a reasonably current basis. A statistical study was made of the data accumulated at TPRC concerning the yield of 3,600 technical and scientific journals cited to date, and it was found that some 80 journals yielded approximately 50 percent of the total articles. Hence, effective January 1965, TPRC subscribed to these journals and began its search directly from these publications. Simultaneously, with the adoption of this procedure, the effort in searching abstracting journals was reduced, by 1967, to seven abstracting journals: Chemical Abstracts, Dissertation Abstracts, International Aerospace Abstracts, Nuclear Science Abstracts, Scientific and Technical Aerospace Reports-NASA, Technical Abstract Bulletin, and U.S. Government Research and Development Reports. As a result of this policy, TPRC is now able to keep abreast of published research results with an average time lag not to exceed six months.

The problem of procuring research documents from the open literature is beginning to assume major proportions especially in the case of foreign literature and special publications of limited distribution. Therefore, TPRC's specialized holdings, which number 35,800 to date, are assuming increasing importance for rapid access to the world literature on thermophysics and thermophysical properties. It is TPRC's experience that literature retrieval programs which yield bibliographies as their end product are becoming increasingly less useful because of the time lapse involved in

procuring the cited documents. In an attempt to remedy this situation, TPRC has supplemented its long-standing practice of submitting bibliographic responses to literature search requests with standard microfiche copies of documents. The conversion of hard copy document holdings into microfiche was completed in 1967.

## 2.2 The Retrieval Guide

The comprehensive edition of the THERMOPHYSICAL PROPERTIES RESEARCH LITERATURE RETRIEVAL GUIDE was published in October 1967 by the Plenum Publishing Corporation [1].

This three-book volume represents the printout of a special computer program and provides quick access to world literature on thirteen thermophysical properties of all matter. Its substance and property coverage are listed in Table E-2.

This volume completes the coverage of the world literature published from 1920 (in some cases earlier) to June 1964 on thirteen thermophysical properties. It is a merger of the material contained in the earlier Volumes 1 and 2 together with the material of Volume 3 which was not published separately. The contents of the three books of the Retrieval Guide are as follows:

Book 1 - Primarily constitutes TPRC's classified Directory of Substances in which information on the thirteen thermophysical properties are reported. Book 1 also contains three other major chapters which greatly enhance its usefulness. These consist of: (1) Guide to TPRC Substance Classification Procedure and Numerical Codes; (2) Dictionary of Synonyms and Trade Names with a Listing of Cross References; and (3) Index to Mixtures.

Book 2 - Contains the classified code entries and publication year of each reference for each property of each material. The classified code entries cover the following:

|                     |  |
|---------------------|--|
| <u>Phys. State:</u> | 1-Solid; 2-Liquid; 3-Gas; 4-Semi-solid; 5-Powder;<br>6-Suspensoid; 7-Sintered; 8-Solid-Gas system;<br>9-Solid-Liquid system.   |
| <u>Subject:</u>     | 1-Theoretical; 2-Experimental; 3-Theo. and Exp.;<br>4-Property values; 5-Theo. and Prop. val.; 6-Exp.<br>and Prop. val.; 7-Theo., Exp., and Prop. val.;<br>8-Survey, Review, Compendia, or Bibliography. |
| <u>Language:</u>    | 1-Eng.; 2-Fr.; 3-Ger.; 4-Dutch; 5-It.; 6-Jap.;<br>7-Rus.; 8-Span.; 9-Other.  |
| <u>Temperature:</u> | 1-Low, 0 to 75 K; 2-Normal, 75 to 1275 K; 3-High,<br>1275 K and up; 4-(Low+Normal); 5-(Normal+High);<br>6-(Low+Normal+High); 7-Not specific  |

TABLE E-2. SUBSTANCE AND PROPERTY COVERAGES OF RETRIEVAL GUIDE\*

## SUBSTANCE COVERAGE - All Matter

|  |        |
|--|--------|
| Elements and chemical compounds  | 9,030  |
| Ferrous and nonferrous alloys  | 9,970  |
| Mixtures   | 13,396 |
| Systems, composites, etc.  | 1,643  |
| Polymers, rubbers, etc.  | 2,600  |
| Refractories   | 961    |
| Glasses  | 1,109  |
| Natural products   | 1,100  |
| Minerals   | 662    |
| Paints, surface finishes, coatings   | 2,632  |
| Slags, scales, aggregates, cermets, fuels, lubricants, fibers, fabrics, pharmaceuticals, insulations, building materials, residues, etc. | 1,967  |
| General  | 46     |
| Total number of substances   | 45,116 |

## PROPERTY COVERAGE - Transport and Thermodynamic Properties Encountered in Heat and Mass Transfer Calculations

|  |         |
|--|---------|
| Thermal conductivity (including accommodation coefficient and thermal contact resistance)                  | 31,050  |
| Specific heat  | 28,020  |
| Viscosity (Newtonian and non-Newtonian; including fluidity)  | 46,870  |
| Thermal radiative properties<br>(Emittance, reflectance, absorption, transmittance, and optical constants) | 9,400   |
| Diffusion coefficient  | 21,720  |
| Thermal diffusivity  | 1,705   |
| Prandtl number   | 504     |
| Total number of reference entries  | 139,305 |

\* This storehouse of information has come from 33,700 references representing 26,562 authors and 3,600 separate scientific and technical journals and books in addition to sources of governmental and industrial reports (e.g., Defense Documentation Center, Clearinghouse for Federal Scientific and Technical Information, Atomic Energy Commission, National Aeronautics and Space Administration, research centers, and the like).

Book 3 - Part A provides bibliographic citations for the 33,700 references covering scientific and technical journals in addition to university dissertations and technical reports of governmental agencies, industrial organizations, and research centers and laboratories. Part B contains an index to names of contributing authors.

In January 1967, the scope of property coverage was increased to include the coefficients of linear and volumetric thermal expansion and surface tension. Furthermore, each thermophysical property is coded separately instead of by groups. For instance, the thermal conductivity, accommodation coefficient, and thermal contact resistance, formerly all coded under the property "thermal conductivity", are now coded separately. Similarly, the five entries under thermal radiative properties are now listed separately. Thus, since January 1967 TPRC maintains coverage of over sixteen thermophysical properties for all materials. They are:

1. Thermal conductivity
2. Accommodation coefficient
3. Thermal contact resistance
4. Thermal diffusivity
5. Specific heat at constant pressure
6. Viscosity
7. Emittance
8. Reflectance
9. Absorptance
10. Transmittance
11. Absorptance to emittance ratio
12. Prandtl number
13. Diffusion coefficient
14. Thermal linear expansion
15. Thermal volumetric expansion coefficient
16. Surface tension

### 2.3 Automation and Computerized Information Storage and Retrieval System

With the installation of the CDC 6500 computer at Purdue University in Summer 1967, TPRC's long-standing need for a remote-accessed time-shared computer capability has been fulfilled. As a result, TPRC now has a fully automated bibliographic search capability to respond to specific inquiries or to process standing requests for a continuing bibliographic service tailored to meet demands for specific technical profiles of individual engineers, scientists, corporations, or laboratories.

Since 1968, TPRC has generated, quarterly, a miniature "Retrieval Guide" for each property in order to serve its own inhouse programs. This service, called the UPDATE PLAN, is also available to subscribers at a very nominal cost.

### **3.0 Data Tables Projects [2]**

#### **3.1 Data Book**

Synthesis of existing fragments of knowledge is as important as so-called original observation. The availability of adequate standard reference tables of numerical data is essential to national progress, economy, and defense.

The three-volume loose-leaf 11" x 17" size TPRC Data Book is well known nationally and, indeed, internationally as the most comprehensive and authoritative reference data source of its kind. In view of this work's continuing rapid growth since 1960, and the extensive physical proportions it has assumed, early in 1967 it was decided to discontinue the present procedure of publication in loose-leaf format and its semi-annual dissemination by TPRC. Instead, this Data Book was restructured and extensively revised and will soon be available through a commercial publisher in the form of formal hard-bound volumes. The forthcoming publication is entitled TPRC SERIES ON THERMOPHYSICAL PROPERTIES OF MATTER and will be described in more detail later.

The last supplement of the data sheets in the loose-leaf format was that of December 1966. All the available sets of the loose-leaf Data Book were exhausted by mid-year 1967. The data sheets produced during 1967 were held in abeyance and will be released for the first time in the forthcoming Series. It is anticipated that the new volumes will become available according to the tentative schedule presented subsequently.

The changeover from the loose-leaf TPRC publication to formal commercial publication has entailed a number of considerations. Significant among these were the following:

1. The Data Book was to be reduced from its unconventional 11" x 17" dimensions to 9-1/4" x 11-1/4" with printing back to back.
2. The organization of the contents were completely restructured in order to improve user's convenience. The new series is organized into volumes by properties.

3. In order to obviate the cumbersome merging of supplements and the associated high cost of dissemination, it was decided that each edition of a volume will be updated, revised and enlarged approximately every five years.
4. For those who have need for the most up-to-date information, TPRC will provide specific inquiry service or one may subscribe to the automatic UPDATE PLAN tailored to meet a specific technical profile of an engineer, scientist, corporation, or laboratory.

The above-outlined procedure closely parallels the concept which TPRC has followed during the past ten years for the dissemination of bibliographic information. That is, the major accomplishments are published in formal volumes through commercial channels while TPRC disseminates materials to maintain its publications and audience on a current basis.

### 3.2 TPRC Series on Thermophysical Properties of Matter

Table E-3 gives an indication of the structure, scope, and publication schedule of the forthcoming TPRC SERIES ON THERMOPHYSICAL PROPERTIES OF MATTER. As shown in Table E-3, to be published in 1969 are Volumes 1 through 8, on which a further summary of statistical data is given in Table E-4.

Each volume of the series comprises three sections: the first section is a text on the theory, estimation, and measurement of the property, the second section presents the available numerical data for the property of the materials, and the third section is a comprehensive material index.

The following brief summaries will serve to characterize each of the active data tables projects.

### 3.3 Projects

#### a. Thermal Radiative Properties (Emittance, Reflectance, Absorptance, and Transmittance)

This group of properties constitutes Volumes 7, 8, and 9 of the new TPRC SERIES. Only Volume 7 (Metallic Elements and Alloys) has now been finished and is ready for publication.

The present tables are organized in a way that is much different from that in the original TPRC Data Book. This is due to the establishment of a new scheme for the designation and categorization of the sub-properties. According to the new scheme, by applying the proper geometric and wavelength descriptors to the prime properties, there are altogether thirty-three sub-properties for any material.

TABLE E-3. PUBLICATION SCHEDULE FOR  
TPRC SERIES ON THERMOPHYSICAL PROPERTIES OF MATTER\*

|  | 1969 | 1970 | 1971 | 1972 | 1973           | 1974           | 1975           | 1976           | 1977           |
|--|------|------|------|------|----------------|----------------|----------------|----------------|----------------|
| Volume 1. Thermal Conductivity of Metallic Elements and Alloys         | 1565 |      |      |      | Second Edition |                |                |                |                |
| Volume 2. Thermal Conductivity of Nonmetallic Solids                   | 1255 |      |      |      | Second Edition |                |                |                |                |
| Volume 3. Thermal Conductivity of Nonmetallic Liquids and Gases        | 640  |      |      |      | Second Edition |                |                |                |                |
| Volume 4. Specific Heat of Metallic Elements and Alloys                | 825  |      |      |      |                | Second Edition |                |                |                |
| Volume 5. Specific Heat of Nonmetallic Solids                          | 1720 |      |      |      |                | Second Edition |                |                |                |
| Volume 6. Specific Heat of Nonmetallic Liquids and Gases               | 390  |      |      |      |                | Second Edition |                |                |                |
| Volume 7. Thermal Radiative Properties of Metallic Elements and Alloys | 1650 |      |      |      |                |                | Second Edition |                |                |
| Volume 8. Thermal Radiative Properties of Nonmetallic Solids           | 880  |      |      |      |                |                | Second Edition |                |                |
| Volume 9. Thermal Radiative Properties of Coatings                     |      | 1690 |      |      |                |                | Second Edition |                |                |
| Volume 10. Thermal Diffusivity   |      | 500  |      |      |                |                |                | Second Edition |                |
| Volume 11. Viscosity   |      | 400  |      |      |                |                |                | Second Edition |                |
| Volume 12. Thermal Expansion of Metallic Elements and Alloys           |      |      | 500  |      |                |                |                |                | Second Edition |
| Volume 13. Thermal Expansion of Nonmetallic Solids                     |      |      | 500  |      |                |                |                |                | Second Edition |

\*The publication schedule shown in the table gives the estimated number of pages for the first edition and the years in which the volumes are to be published. After the second edition, subsequent editions of each volume will be released at intervals of five years.

TABLE E-4. SUMMARY OF STATISTICAL DATA ON VOLUMES 1 TO 7 OF  
 "TPRC SERIES ON THERMOPHYSICAL PROPERTIES OF MATTER"

|           |   | No. of<br>Pages* | No. of<br>Curves | No. of<br>References** |
|-----------|---|------------------|------------------|------------------------|
| Volume 1. | Thermal Conductivity of<br>Metallic Elements and Alloys         | 1565             | 5539             | 1013                   |
| Volume 2. | Thermal Conductivity of<br>Nonmetallic Solids                   | 1255             | 4627             | 598                    |
| Volume 3. | Thermal Conductivity of<br>Nonmetallic Liquids and Gases        | 640              | 1505             | 725                    |
| Volume 4. | Specific Heat of Metallic<br>Elements and Alloys                | 825              | 1186             | 428                    |
| Volume 5. | Specific Heat of Non-<br>metallic Solids                        | 1720             | 1009             | 449                    |
| Volume 6. | Specific Heat of Non-<br>metallic Liquids and Gases             | 390              | 863              | 595                    |
| Volume 7. | Thermal Radiative Properties<br>of Metallic Elements and Alloys | 1650             | 5309             | 352                    |

\* Estimated

\*\* These are the references to data sources only, not including those references to the text on the theory, estimation, and measurement of the respective thermophysical properties.

Since Volume 7 is now essentially finished, the major efforts are concentrated on the processing of data on coatings and nonmetallic solids so that Volumes 8 and 9 can be published in 1969 and 1970 respectively. The new classification scheme for coatings is now "finalized" after considerable study by the TPRC staff in consultation with several national experts.

Although in Volume 3 of the Retrieval Guide there are only 2,829 references on thermal radiative properties (8.4 percent), in recent years the number of new research documents on the thermal radiative properties has increased steadily and rapidly. Presently, TPRC's acquisition rate is about 6,000 papers per year, 20 percent related to radiative properties. Also, 50 percent of the papers pertaining to radiative properties contain information on coatings. Therefore, it is a very arduous task just to remain current by processing the incoming documents, 1,200 per year, and it has become a standing practice to try to finish the data processing for the most current research documents first, and then to work backwards on the earlier documents. A similar situation is present in the thermal conductivity and specific heat projects.

#### b. Thermal Conductivity

Thermal conductivity constitutes Volumes 1, 2, and 3 of the new TPRC SERIES. Data compilation for the thermal conductivity of the elements is totally completed and is being maintained on a current basis.

In Volume 3 of the Retrieval Guide, which contains 33,700 references, there are 7,329 references on thermal conductivity, i.e., 21.7 percent (neglecting the relatively small number of references on accommodation coefficient and thermal contact resistance). The present rate of document input into TPRC's Information Storage and Retrieval System is about 6,000 per year. If the past ratio remains the same, there will be 1,300 new documents per year on thermal conductivity entering the System.

In the forthcoming Volumes 1, 2, and 3 of the TPRC SERIES, the thermal conductivity of all metals and alloys, which are organized into seven groups, are included in Volume 1. Volume 2 presents data for thirty groups of nonmetallic solids. Volume 3 contains the critically evaluated and recommended values for 58 fluids which are organized into four groups; for the elements recommended

values are given for solid, saturated liquid, saturated vapor, and gaseous states while for the other three groups of fluids recommended values are given for saturated liquid and gaseous states only.

The three volumes on thermal conductivity contain 2,287 references to data sources. Past experience indicates that only one out of three to four earlier research documents and only one out of two to three more recent documents contains original experimental data. Therefore, to have 2,287 references to data sources, over 7,000 research documents must have been processed.

#### c. Specific Heat

Specific heat constitutes Volumes 4, 5, and 6 of the new TPRC SERIES. Tables on the specific heat of the elements and of all the important alloys, compounds, and mixtures have been prepared. Data compilation on the specific heat of metallic elements and alloys and nonmetallic solids has been done here at TPRC while the work on nonmetallic liquids and gases has been done at TPRC's Overseas Branch in Japan.

The specific heat of all metals and alloys, which are organized into four groups, are included in Volume 4. Volume 5 presents data for twenty-four groups of nonmetallic solids. Volume 6 contains the critically evaluated and recommended values for 56 fluids organized into four groups.

In Volume 3 of the Retrieval Guide there are 6,978 references on specific heat, i.e., 20.7 percent of the 33,700 references. If the past ratio remains the same, there will be 1,240 new documents per year on specific heat entering the System.

#### d. Thermal Diffusivity

Thermal diffusivity will constitute Volume 10 of the new TPRC SERIES. The work on this property has been greatly accelerated and all the previous tables have been extensively updated and revised and new research documents are being processed. There are 597 documents on thermal diffusivity in the Retrieval Guide, i.e., 1.7 percent. About 100 new documents enter the System each year.

#### e. Thermal Expansion

Thermal expansion will constitute Volumes 12 and 13 of the new TPRC SERIES. The work on this property had been active in 1964-66, and suspended

until mid 1968. This work has been reactivated and Volumes 12 and 13 will be published in early 1971.

f. Viscosity

Viscosity will constitute Volume 11 of the new TPRC SERIES. The work on this property had been suspended from 1964 to 1966. Starting early 1967, this work was reactivated in TPRC's European Branch at the Belgian Institute for High Pressure, Brussels, Belgium, with Dr. P. Hestermans as Senior Investigator. This Volume 11 is planned to be published in early 1970.